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ФЕДЕРАЛЬНОЕ АГЕНТСТВО ПО ОБРАЗОВАНИЮ
Государственное образовательное учреждение высшего профессионального образования
«НАЦИОНАЛЬНЫЙ ИССЛЕДОВАТЕЛЬСКИЙ ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ»

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КУРС АНГЛИЙСКОГО ЯЗЫКА ПО ФИЗИКЕ АКТУАЛЬНЫЕ ПРОБЛЕМЫ ЯДЕРНОЙ БЕЗОПАСНОСТИ

Книга для студента

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Учебное пособие “Current issues of Nuclear Security” составлено в соответствии с образовательной программой Национального исследовательского томского политехнического университета по дисциплине «Профессиональный иностранный язык».

Цель пособия – формирование у студентов ядерно-энергетических специальностей навыков профессиональной коммуникации на английском языке. Пособие содержит тщательно отобранные оригинальные современные тексты по ядерным технологиям. К ним разработана система упражнений, нацеленных на овладение общенаучной лексикой, а также терминологией, относящейся к профессиональной сфере деятельности студентов. Упражнения к текстам имеют коммуникативную направленность и позволяют вовлекать студентов во все виды речевой деятельности.

Учебное пособие “ Current issues of Nuclear Security” предназначено для студентов ядерно-энергетических специальностей, продолжающих изучение иностранного языка в вузе.

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Contents

UNIT 1

ATOMIC NATURE OF MATTER

Warm up.

What is atom?

Words for understanding the text.

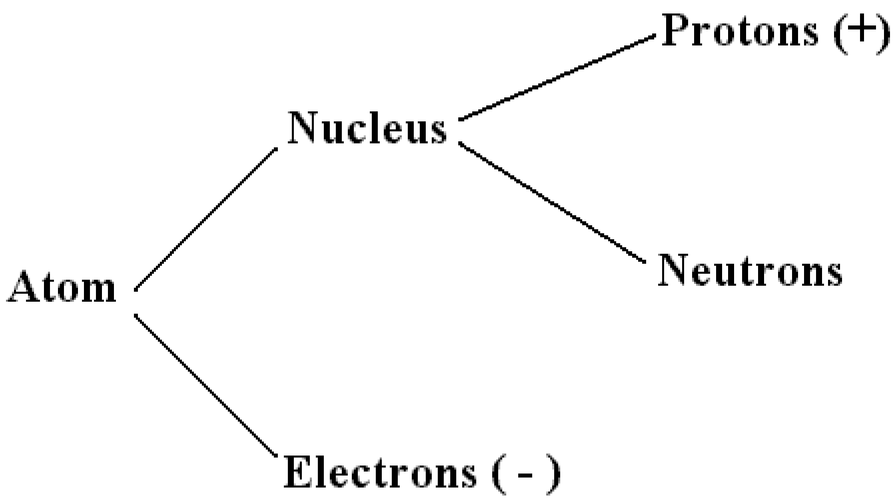
Proton, neutron, electron, nucleus, atom, isotope.

Activity 1

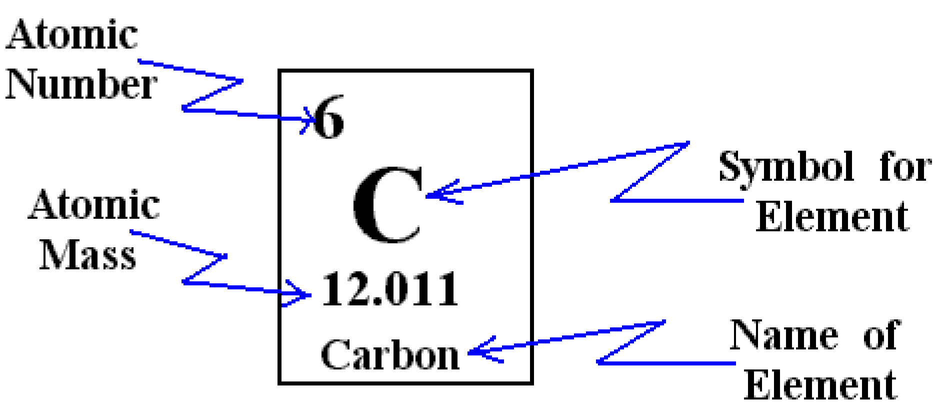
Read the text very carefully to understand it and do the exercises below.

Atomic Nature of Matter

Atoms consist of three basic subatomic particles. These particles are the proton, the neutron, and the electron. Protons are particles that have a positive charge, have about the same mass as a hydrogen atom, and exist in the nucleus of an atom. Neutrons are particles that have no electrical charge, have about the same mass as a hydrogen atom, and exist in the nucleus of an atom. Electrons are particles that have a negative charge, have a mass about eighteen hundred times smaller than the mass of a hydrogen atom, and exist in orbital shells around the nucleus of an atom. The Bohr model of the atom consists of a dense nucleus of protons and neutrons (nucleons) surrounded by electrons traveling in discrete orbits at fixed distances from the nucleus. Nuclides are atoms that contain a particular number of protons and neutrons.



Isotopes are nuclides that have the same atomic number and are therefore the same element, but differ in the number of neutrons. The atomic number of an atom is the number of protons in the nucleus. The mass number of an atom is the total number of nucleons (protons and neutrons) in the nucleus. The notation AZ X is used to identify a specific nuclide. "Z" represents the atomic number, which is equal to the number of protons. "A" represents the mass number, which is equal to the number of nucleons. "X" represents the chemical symbol of the element. Number of protons = Z Number of electrons = Z Number of neutrons = A - Z



The stability of a nucleus is determined by the different forces interacting within it. The electrostatic force is a relatively long-range, strong, repulsive force that acts between the positively charged protons. The nuclear force is a relatively short-range attractive force between all nucleons. The gravitational force the long range, relatively weak attraction between masses is negligible compared to the other forces.

(From: http://physics.info/atoms/)

Activity 2

Match the words with the definitions.

1. *Smallest particle that is still an element. Consists of: proton and neutron in the nucleus and electrons*	a. *Neutron*
2. *Electrically neutral nucleon that is in an atomic nucleus*	b. *Proton*
3. *The principal building block of the nucleus. Composed of quarks. If it is electrically neutral it is called a neutron. If it is electrically charged it is called a proton*	c. *Nucleus*
4. *A. Positively charged center of an atom. B. Contains protons and neutrons (nucleons). C. Has most of the mass. D. Has a fraction of the volume.*	d. *Atom*
5. *(+) charged particle in the nucleus of an atom.*	e. *Nucleon*

Activity 3

Group any words which go together.

1. *positive*
2. *building*
3. *atomic*
4. *subatomic*
5. *different*

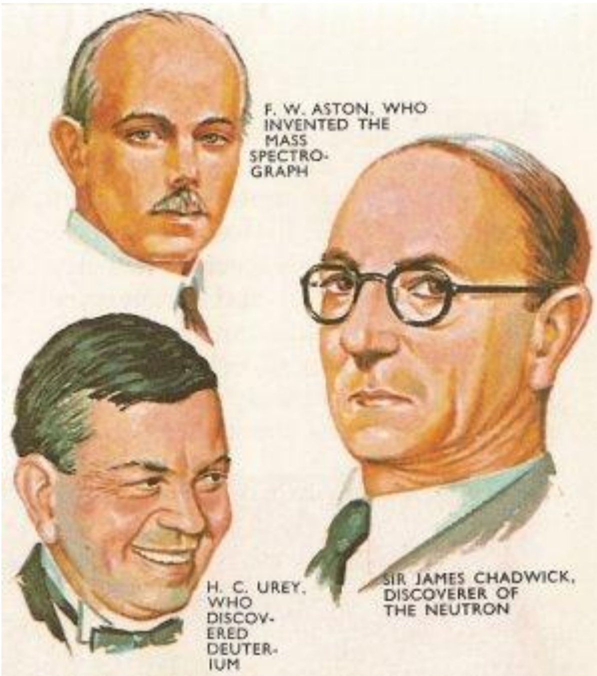
a. *charge*
b. *block*
c. *number*
d. *particle*
e. *force*

Activity 4

Before reading the following text, work with a partner and discuss the questions below. Base your answers on your possible knowledge of the topic. Then read the text and check your guesses.

- What is isotope?
- How many isotopes does oxygen have?
- How many isotopes does hydrogen have?
- What do you know about the discovery of isotopes?

The discovery of isotopes



By the end of the 18th century many facts were known about the way that chemical elements combine. For example, it was known that if 1 gram of element *A* reacts with 10 grams of element *B*, then 2 grams of *A* will react with 20 grams of *B*. This was explained, in 1803, by the chemist John Dalton, who suggested that all matter is composed of tiny particles, called atoms. In Dalton's theory, all the atoms of the same element had the same weight, and elements differed from each other because they were composed of atoms of different weights.

From measurements of the amounts of different substances which took part in chemical reactions, it was possible to measure the atomic weight (also known as the relative atomic mass) of these elements. The atomic weight of an element is the weight of an atom of the element compared with that of a hydrogen atom.

In 1815, William Prout noticed that most atomic weights were almost exactly whole numbers, so that the weight of each atom was almost exactly a multiple of that of a single hydrogen atom. For example, the nitrogen atom is 14 times, and the oxygen atom 16 times, as heavy as the hydrogen atom. This led him to suggest that all atoms were composed of hydrogen atoms. However, when more accurate measurements of atomic weights were made, it was found that they were not exactly whole numbers. Chlorine, for example, was found to have an atomic weight of 35.5. This brought about the downfall of Prout's hypothesis, and it was not until the atomic scientists of the 20th century made their discoveries about the structures of individual atoms that a proper explanation of the values of atomic weights could be found.

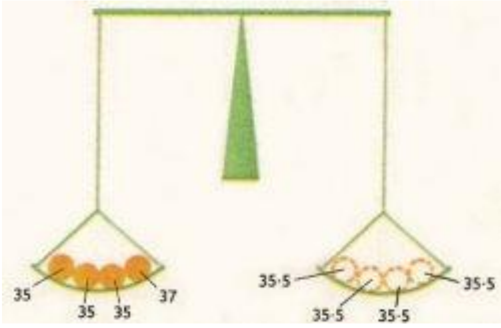
In 1897, J. J. Thomson discovered the electron, and in 1911 Ernest Rutherford discovered that the atom consists of a small positively charged core, called the nucleus, surrounded by a number of negatively charged electrons. The positive charge on the nucleus is exactly equal to the total of negative charges carried by the electrons.

The number of units of positive charge on the nucleus of the atom is called the atomic number of the atom, and in 1913 H. G. J. Mosely found the atomic numbers of several elements.

It is the number and arrangement of electrons in the atom which determines its chemical behavior. The atomic weights merely determine the amounts of each element which take part in a chemical reaction.

It is therefore possible to have two atoms of the same element of different atomic weight, but which have identical chemical properties because the atomic numbers (and therefore the numbers of electrons in the atoms) are the same. Such atoms are called isotopes. Francis W. Aston, in 1919, using a mass spectrograph, was able to separate isotopes of different elements. In the mass spectrograph it is possible to separate atoms of different atomic weights, and to determine how much of each isotope is present.

Ordinary chlorine consists of 3 atoms of 35Cl to 1 atom of 37Cl so the measured atomic weight (i.e. the average atomic weight) = 35.5



By making such measurements, it has been possible to find out how much of each isotope exists in each element, and to explain the values of atomic weights of the elements. For example, chlorine has two naturally occurring isotopes of atomic weights 35 and 37, and it has been found that there is almost three times as much of the lighter isotope as there is of the heavier one. This leads to an average atomic weight of (3 × 35 + 1 × 37)/4 = 35.5.

The atomic weights of the isotopes of the elements are very nearly whole numbers, and the reason for this became apparent when James Chadwick, in 1932, discovered the neutron. The neutron is an uncharged particle of mass one. It became clear that the atomic nucleus was composed of protons (particles of mass one carrying a single positive charge) and neutrons. For example, the nucleus of helium, which has an atomic weight of 4 and an atomic number of 2, consist of 2 neutrons and 2 protons. The nucleus of the chlorine isotope atomic weight 35 consists of 17 protons and 18 neutrons, whilst the chlorine isotope atomic weight 37 consists of 17 protons and 20 neutrons. The atomic number of both isotopes is 17.

(From: http://www.daviddarling.info/encyclopedia/I/isotope.html)

Activity 5

Read the text and complete the gaps in sentences below with the correct word or phrase.

a. mass number
b. protons

c. nucleons
d. neutrons
e. periodic table
f. chemical element
g. atomic number

Isotopes are variants of a particular _____1_____. While all isotopes of a given element share the same number of ____2_____, each isotope differs from the others in its number of ____3____. The term isotope is formed from the Greek roots isos ("equal") and topos ("place"). Hence: "the same place," meaning that different isotopes of a single element occupy the same position on the ____4_____. The number of protons within the atom's nucleus uniquely identifies an element, but a given element may in principle have any number of neutrons. The number of ___5____ (protons and neutrons) in the nucleus, known as the ____6_____, is not the same for two isotopes of any element. For example, carbon-12, carbon-13 and carbon-14 are three isotopes of the element carbon with mass numbers 12, 13 and 14 respectively. The _____7______ of carbon is 6 (every carbon atom has 6 protons); therefore the neutron numbers in these isotopes are 6, 7 and 8 respectively.

Activity 6

Decide if the sentences are True or False.

1. Thomson discovered that the atom consists of a small positively charged core, called the nucleus, surrounded by a number of negatively charged electrons.
2. Isotopes are nuclides that have the same atomic number and are therefore the same element, but differ in the number of neutrons.
3. The number of units of positive charge on the nucleus of the atom is called the atomic mass of the atom, and in 1913 H. G. J. Mosely found the atomic numbers of several elements.
4. Francis using a mass spectrograph was able to separate isotopes of different elements.
5. In Dalton's theory, all the atoms of the same element had the different weight, and elements differed from each other because they were composed of atoms of different weights.

THE WORLD OF SUBATOMIC PARTICLES

Warm up.

a. Imagine what the text “the world is made of subatomic particles”
b. What do you know about particle?

c. What can you tell us about properties of subatomic particles?

Activity 7

Work with a partner. Choose any object around you and as a future physicist describe what it is made of. Discuss your descriptions.

Activity 8

For each word in A find in B its equivalent having roughly the same meaning.

1. abrupt
2. immense
3. rapid
4. incredible
5. drastic
6. to prevail
7. to presume
8. to perceive

a. quick
b. unlimited, immeasurable
c. very powerful
d. improbable, impossible to believe
e. sudden and surprising
f. to understand (see or notice)
g. to be most common or general
h. supposed to be true without proof

Reading

Read the text carefully and explain the phenomenon of "phase change". Say why this phenomenon is of interest to physicists. Retell the text.

Explain the meaning of the following words:

Density, property, liquid, particle

The world is made of subatomic particles

According to contemporary physicists, the world is made of several types of objects, collectively referred to as subatomic particles. (These particles can also be thought of as manifestations of something yet more fundamental, known as quantum fields.) There may be as many as 1089 identical copies of some of these particles in the present universe. The forms of matter familiar to us, both living and nonliving, on the earth and in the heavens, are all composed of various combinations of only three types of subatomic particles – protons, neutrons, and electrons. Dozens of other types of particles can be produced momentarily in the laboratory, however, and are thought to have existed in large numbers in the early universe.

All subatomic particles are defined by a few qualities that they may possess, such as mass, spin, and electric charge. Two particles are of the same type, if all of these qualities agree. Otherwise, they are considered to be different particles. Particles of the same type are, as far as we know, truly identical in these properties of mass, spin, and charge rather than just very similar. If all photons, the particles that make up light, were not identical, lasers would not operate.

The subatomic particles readily convert into one another when they collide.

The kinetic energy of motion of light particles can be converted into the energy associated with mass (rest energy) of heavy particles. In many cases, even isolated particles can convert spontaneously into others, if the latter are less massive. In all such transformations, only a few properties, such as the total electric charge, remain unchanged. The subatomic particles do not act like the changeless building blocks imagined by some Greek philosophers. In the last few years, physicists have realized that even those subatomic particles which exist have changed radically over the lifetime of the universe. It appears that evolution takes place on all levels of matter, not just on the more complex levels of living things. The driving force behind this evolution is the expansion of the universe, which by changing the environment in which particles are found, changes the particles themselves. Only twenty years ago, the idea that the properties of subatomic particles might depend on their environment would have been considered heresy.

Under the conditions in which physicists usually observe subatomic particles, their defining properties are not perceived to vary, giving these properties an illusion of stability. However, under the immense temperatures and densities that prevailed in the early stages of the universe, the properties, such as mass, of some particles would have been very different from what they are now. This situation is related by nature to the variability of a liquid such as water. Under a fairly wide range of temperatures water remains liquid and its properties do not change much whatever the temperature within this range. But if the water is subjected to much lower temperatures, or is heated to above 100° Celsius, its properties change abruptly. The liquid becomes a solid (ice) or a gas (water vapour). This type of change, in which the properties of a substance change drastically as a result of a small variation in its environmental conditions is called a "phase change" by physicists.

The presumed change in the properties of subatomic particles at very high temperatures is also considered to be a phase change, one that involves the properties of space, as well as of the particles in it. In other words, the particles do not react directly to a temperature change but to some alteration in space, the medium, in which they find themselves.

It is easy to boil or freeze water, but very difficult to duplicate in the lab the extreme conditions present at the birth of the universe. Yet physicists have become convinced of the theory that atomic particles, and space itself, went through momentous phase changes during and after the Big Bang. The rapid cooling that followed that primordial explosion is thought to have generated several phase changes. After an incredibly short time (perhaps a microsecond), the subatomic stuff of the young universe became stabilized, combining into the particles that make up matter today.

Activity 9

Translate the following sentences from the text into Russian.

1. The world is made of several types of objects, collectively referred to as subatomic particles.
2. All subatomic particles are defined by a few qualities that they may possess, such as mass, spin, and electric charge.
3. If all photons, the particles that make up light, were not identical, lasers would not operate.
4. The subatomic particles readily convert into one another when they collide.
5. The subatomic particles do not act like the changeless building blocks imagined by some Greek philosophers.
6. The rapid cooling that followed that primordial explosion is thought to have generated several phase changes.

Activity 10

Correct the mistakes in these sentences.

1. The world made up of 1089particles.
2. The particles were knew to be doubly charged.
3. Photons have be studied as elements of quantum computers.
4. The inner structure of atoms could is obtained by the study of collisions.
5. We will are taken the information related to quarks' groups.
6. The properties of subatomic particles had being observed for many years.
7. The examples of particle interaction were being think about.
8. The space objects being treated as particles.

UNIT 2

CHART OF NUCLIDES

Before reading the following text, work with a partner and discuss the questions below. Base your answers on your possible knowledge of the topic. Then read the text and check your guesses.

- What is a chart of the nuclides?
- What does a typical block for a stable nuclide contain?
- What does a typical block for an unstable nuclide contain?
- What information includes the chart of the nuclides?
- What is a nuclear "magic numbers"?
- What are the core are more stable?

Activity 1

Match the words with the definitions

1. Nuclide	a. a subatomic particle with a negative elementary electric charge
2. Isotope	b. subatomic particle with a positive electric charge of elementary charge
3. Atomic mass	c. a subatomic hadron particle which has no electric charge and a mass slightly larger than that of a proton
4. Electron	d. one of the particles that makes up the atomic nucleus
5. Proton	e. an atomic species characterized by the specific constitution of its nucleus
6. Neutron	f. energy required to split a nucleus of an atom into its component parts
7. Nucleon	g. variants of a particular chemical element
8. Nucleus	h. a basic unit of matter that consists of a dense central nucleus surrounded

	by a cloud of negatively charged electrons
9. Atom	i. a very dense region consisting of protons and neutrons at the center of an atom.
10. Binding energy	j. the mass of a specific isotope, most often expressed in unified atomic mass units

Nuclide Charts

The origin of the nuclide chart is somewhat uncertain. In his autobiography, Segre mentions the "Segre Chart" compiled with the help of his wife at Los Alamos in 1945. After the war it was declassified and published, selling more than 50,000copies. Segre also mentions that the "first modest table of isotopes was published by a student in our Rome group in the 1930s". One of the earliest nuclides charts as complied by G. Friedlander and M. Perlman and published by the General Electric Company in 1946. In contrast to the earlier charts by Fea and Segre, this chart had the proton number as the vertical axis and the neutron number as the horizontal axis. The current version of this chart is the 16th edition.

Nuclide charts are based upon the proton-neutron model of the nucleus and are essentially a plot of the number of protons versus the number of neutrons in stable and unstable nuclei. In these charts, the vertical and horizontal axes represent the number of protons and neutrons respectively in the nucleus as shown in Fig. 1.

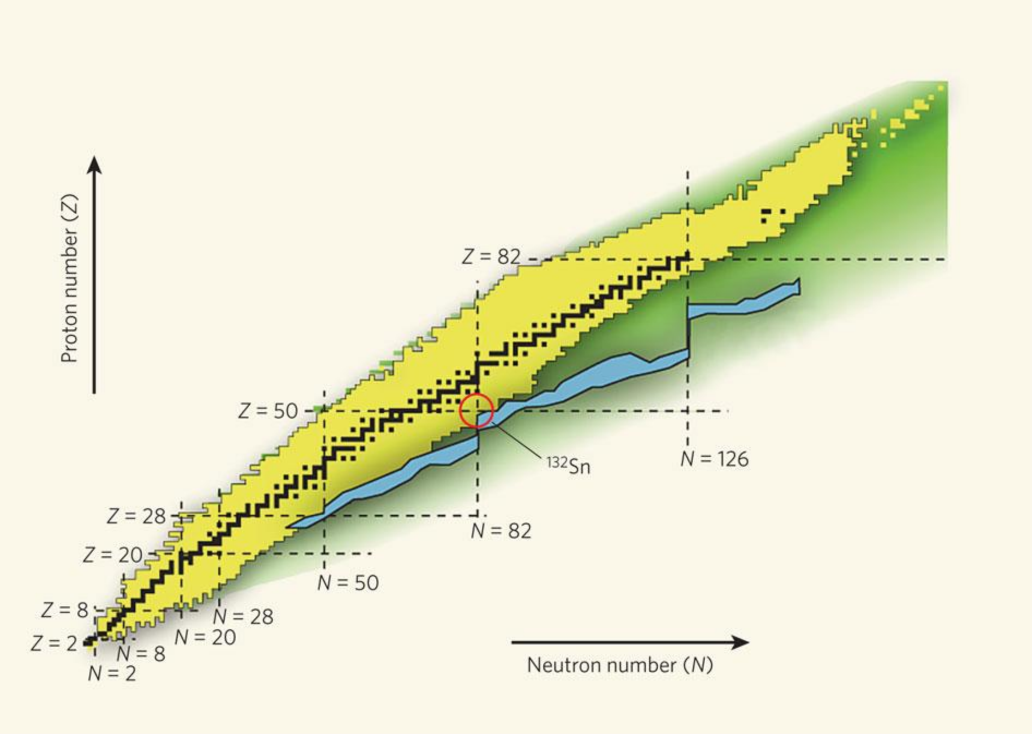


Fig. 1.Nuclide stability diagram. Stable nuclides (black) fall in a narrow range of neutron to proton ratio. Unstable nuclides (yellow) have neutron to proton ratios

outside this range. Also shown are the proton and neutron magic numbers represented by the horizontal and vertical lines

The diagram plots the number of protons (*Z*) against the number of neutrons (*N*) for stable isotopes (black), radioactive isotopes that have been produced (yellow), radioactive isotopes that may exist but have not yet been observed (green), and isotopes that are thought to be produced in a succession of nucleon synthesis reactions called the r-process (blue). The dashed lines denote the nuclear 'magic numbers', which correspond to nuclei that are generally more stable against decay than other isotopes. Jones and colleagues show that the neutron-rich radioactive tin isotope 132Sn ($Z = 50$, $N = 82$), which had been anticipated to be a 'doubly magic' isotope (it lies at the intersection of two 'magic' lines), is indeed doubly magic.

The charts contain information on the basic nuclear properties of known nuclides. Each nuclide is represented by a box containing basic nuclear data. This data consists of the half-life, neutron cross-sections, main gamma lines etc. of that nuclide. An important characteristic of the charts is the use of color to denote the mode of decay, half-life, or cross-sections. If the nuclide has one or more stable states, the box is subdivided into smaller boxes for each state. The main nuclide charts in use world-wide are the Karlsruhe (Germany), Strasbourg (France), General Electric or KAPL (US), and the JAERI (Japan) charts.

It can be seen that stable isotopes lie within a relatively narrow range indicating that the neutron to proton ratio must have a certain value or range of values to be stable. Radioactive nuclei (yellow squares in Fig. 1) mostly lie outside this range. The plot also shows that for low atomic numbers, the neutron to proton ratio is unity. At higher atomic numbers, this value increases indicating a higher ratio of neutrons to protons in heavy atoms.

The extremities of the yellow regions above and below the region of stability are known as the proton and neutron “drip-lines” beyond which nuclei are extremely unstable (i.e. if a nucleon is added it will “drip” out again). As nucleons are successively added to a nucleus on the stability line, the binding energy of the last nucleon decreases steadily until it is no longer bound and the nucleus decays by either neutron or proton emission.

Nuclei with even numbers of protons and neutrons are more stable than nuclei with other combinations of neutrons and protons. For uneven numbers of protons and neutrons, there are only very few stable nuclides. The stability of nuclei is extremely significant for special numbers of protons and neutrons. These (magic) numbers are2, 8, 20, 28, 50, 82 and 126 and correspond to full shells in the shell model of the nucleus. The element tin with the proton number Z = 50, for example, has 10 stable isotopes, more than all other elements.

When the proton and neutron numbers both have magic values, the nucleus is said to be “doubly magic”. Doubly magic, stable nuclides are for example4He, the alpha particle, as well as the nuclide208Pb, which is reached in several decay processes, for example in the decay chain of232Th.

In addition to providing the most important basic nuclear data, the charts allow one to trace out radioactive decay processes and neutron reaction paths.

The Strasbourg Nuclide Chart was developed by Dr. Mariasusai Antony from the Louis Pasteur University of Strasbourg. Approximately 5000 copies of the1992 version were sold in more than 40 countries. This original version contained data on approximately 2550 ground states and 571 isomers. An updated version was published in 2002. The new chart displays about 2900 isotopes in the ground states and about 700 isomers. The chart is a booklet of 44 A4 formatted pages. The front cover page exhibits a stork, symbol of the region of Alsace for which Strasbourg is the capital. The colors blue, white and red (actually reddish-brown) were chosen to indicate the tri-colors of France.

Continuing a half-century tradition, Knolls Atomic Power Laboratory (KAPL) has recently published the 16th edition (2003) of its Chart of the Nuclides in both wall chart and textbook versions. The first edition was published by the General Electric Company in 1946. Evaluated nuclear data is given for about 3100 known nuclides and 580 known isomers. For each nuclide the half-life, atomic mass, decay modes, relative abundances, nuclear cross-section, and other nuclear properties are detailed. The updated chart includes approximately 300 new nuclides and 100 new isomers not found in the 15th (1996) edition. There has been at least one change in more than 95% of the squares on the chart.

The first edition of the JAERI nuclide chart was published in February 1977. Since then the chart has been revised every 4 years, i.e. 1980, 1984, 1988, 1992,1996, with the most recent edition appearing in 2000. In total, seven editions have been published. Approximately 2000 copies of each edition were printed, most of which are distributed to the Japanese nuclear data community and international organizations. The chart comes as an A4-sized booklet.

Activity 2

Give the definitions of the notions below.

- chart
- axis
- neutron-to-proton ratio
- proton-neutron model of the nucleus
- box is
- “drip-lines”
- “doubly magic” nucleus

Activity 3

Fill in the gaps (1-6) with the words. There is one extra word which you don’t need to use.

- neutron-to-proton

- proton
- stability curve
- mass numbers
- excess
- axes
- nucleon
-

Figure 1 shows the distribution of the stable nuclides plotted on the same **1__________** as the Chart of the Nuclides. As the **2__________** become higher, the ratio of neutrons to protons in the nucleus becomes larger. For helium-4 (2 protons and 2 neutrons) and oxygen-16 (8 protons and 8 neutrons) this ratio is unity. For indium-115 (49 protons and 66 neutrons) the ratio of neutrons to protons has increased to 1.35, and for uranium-238 (92 protons and 146 neutrons) the neutron-to-proton ratio is 1.59.If a heavy nucleus were to split into two fragments, each fragment would form a nucleus that would have approximately the same 3__________ ratio as the heavy nucleus. This high neutron-to-proton ratio places the fragments below and to the right of the 4__________ displayed by Figure 6. The instability caused by this 5__________ of neutrons is generally rectified by successive beta emissions, each of which converts a neutron to a6__________ and moves the nucleus toward a more stable neutron-to-proton ratio.

Activity 4

Choose the correct answer.

1. Who complied one of the earliest nuclides charts and published it?
a. G. Friedlander and M. Perlman
b. Segre
c. Karlsruhe

2. **As shown in the table of nuclides in yellow?**
a. isotopes that are thought to be produced in a succession of nucleosynthesis reactions
b. radioactive isotopes that may exist but have not yet been observed
c. radioactive isotopes that have been produced

3.What do the dotted lines in the chart of nuclides?
a. nuclear 'magic numbers', which correspond to nuclei that are generally less stable against decay than other isotopes
b. nuclear 'magic numbers', which correspond to nuclei that are generally more stable against decay than other isotopes
c. nuclear 'magic numbers', which correspond to nuclei that are generally not stable against decay than other isotopes

4 What are nuclear data are not included in the chart box?

a. half-life
b. neutron cross-sections
c. atomic mass

5. Nuclei with even numbers of protons and neutrons are … than nuclei with other combinations of neutrons and protons.

a. more stable
b. less stable

6.The nucleus is said to be "doubly magic", when…

a. the proton and neutron numbers both have magic values
b. all protons in nucleus have magic values
c. all neutrons in nucleus have magic values

Activity 5

Before reading the following text, work with a partner and discuss the questions below. Base your answers on your possible knowledge of the topic. Then read the text and check your guesses.

1. Do you know about The Karlsruhe Chart of the Nuclides?
2. What is a half-life?
3. What is gamma energy?
4. What is electron capture?
5. What is decay ratio?
6. What is transuranics?

Activity 5

Work in small groups and prepare small (3 minutes) report on following themes:

a) Nuclides
b) Atomic nucleus
c) Isotopes

A Short History of the Karlsruhe Nuclide Chart

The Karlsruhe Chart of the Nuclides was initiated by Professor Walter Seelmann-Eggebert from the Technische Hochschule (TH) Karlsruhe to display basic nuclear data (half-lives, decay modes, particle energies, and most probable gamma energies). The Karlsruhe chart of the nuclides was based on an earlier chart by G. Friedlander and M. L. Pearlman in the General Electric Chart of the Nuclides.

Fig. 1. Original Karlsruhe Chart of the Nuclides from 1958

1st Edition, 1958: The first edition appeared as a wall chart in DIN A0 format. Colored boxes were used to indicate the decay modes (black = stable nuclide, red =β+ decay or electron capture, blue = β− decay, yellow = alpha decay, white = isomeric transition). In addition a DIN A4 version was available as a collection of sheets with an explanatory brochure for desktop use. It was prepared by W. Seelmann-Eggebertand G. Pfennig both from the Institute of Radiochemistry in the Karlsruhe Research Centre and the TH Karlsruhe. The data used in the chart was from the Nuclear Data Sheets of the National Research Council and the Table of Isotopes by D. Strominger, J. M. Hollander, G.T. Seaborg. The original chart contained data on 267 stable and1030 unstable nuclides and more than 220 isomeric states from the, at that time, 102known elements from hydrogen to nobelium.

2nd Edition, 1961: Following on the interest shown in the first edition, a second edition was published in 1961 with additional authors H. Munzel and G. Zundel – also from the Institute of Radiochemistry. A new feature was the introduction of colored corners of different size to indicate the branching ratio of the decay mode. The second edition contained information on 103 elements, and data on approximately 70 new unstable nuclides.

3rd Edition, 1968: Due to the increasing use of the Karlsruhe chart of the nuclides worldwide, a third edition was produced in 1968 with explanatory text in four languages – German, English, French and Spanish. The color green was introduced to indicate spontaneous fission, and atomic masses were based on 12C.

Instead of single DIN A4 sheets, the desktop version was printed in a special arrangement in a strip folded to DIN A4 format. The third edition contained information on 105 elements and more than 1600 nuclides – an increase of 250 over the 2nd edition.

4th Edition, 1974: Much of the data in the 3rd edition had to be revised to reflect the higher accuracy data obtained from the use of Ge detectors. Owing to the improved experimental technique, new data had become available for many short-lived fission products. The 4th edition contained data on more than 1900 nuclides.

Fig. 2. Left: Prof.W. Seelmann-Eggebert with the original 1st edition (1958) of the Karlsruhe Chart of the Nuclides. Right: The co-authors H. Klewe-Nebenius (left), G. Pfennig (centre), H. Munzel (right) with the revised 6th edition (1998/2001).

5th Edition, 1981: The fifth edition was authored by W. Seelmann-Eggebert, G. Pfennig, H. Munzel, and H. Klewe-Nebenius. New decay modes of double beta decay($2\beta^-$) and proton decay (p, color orange) were introduced. To discriminate between direct and β-delayed particle emission, new notations for the latter (βp,βn, β2n, βsf, etc.) were introduced. The 5th edition contained data on more than 2220 nuclides.

6th Edition, 1995: The sixth edition was published in 1995 – more than a decade after the 5th edition – by G. Pfennig and H. Klewe-Nebenius and dedicated to Professor W. Seelmann-Eggebert who died in 1988. In the meantime, four new heavy elements (108–111) had been discovered at the Gesellschaft fur Schwerionenforschung (GSI) at Darmstadt. New decay modes of cluster emission e. g. C-14, O-20, Ne-24etc. indicated by the color violet) were added. The 6th edition contained data on approximately 2690 nuclides from 111 elements.

Revised 6th Edition, 1998/2001: the sixth edition was revised in 1998 to include data on the newly discovered element 112, new names for elements 104–108, new decay data for some transuranics and 150 mostly short-lived nuclides far from the line of stability.

Since the introduction of the Karlsruhe Chart of Nuclides, over 150,000 copies of the wall chart and 203,000 copies of the brochure with the folded chart have been printed. For the sixth edition more than 15,000 wall charts and 45,000 brochures were printed.

Activity 6

Give the definitions of the notions below.

1. nuclear data
2. box
3. chart
4. electron capture
5. axis
6. β− decay
7. alpha decay

Activity 7

Fill in the gaps (1-6) with the words. There is one extra word which you don't need to use.

isomeric states, radiochemistry, datasheets, axis, edition, alpha decay, J. M. Hollander

1st Edition, 1958: The first ________appeared as a wall chart in DIN A0 format. Colored boxes were used to indicate the decay modes (black = stable nuclide, red =β+ decay or electron capture, blue = β− decay, yellow =_________, white = isomeric transition). In addition a DIN A4 version was available as a collection of sheets withan explanatory brochure for desktop use. It was prepared by W. Seelmann-Eggebertand G. Pfennig both from the Institute of ________ in the Karlsruhe Research Centre and the TH Karlsruhe. The data used in the chart was from the Nuclear ________ of the National Research Council and the Table of Isotopes by D. Strominger,________ , G.T. Seaborg. The original chart contained data on 267 stable and1030 unstable nuclides and more than 220 ________ from the, at that time, 102known elements from hydrogen to nobelium.

Activity 8

Correct the mistakes in each line (some lines may be correct)

6th Edition, 1995: The fourth edition was published in 1995 – more than a decade after the 5th edition – by G. Pfengler and H. Klewe-Nebenius and dedicated to Professor W. Seelmann-Eggebert who was born in 1988. In the meantime, four new heavy elements (108–111) had been discovered at the Gesellschaft fur Schwerionenforschung (GSI) at Berlin. New decay modes of cluster emission e. g. C-14, O-20, Ne-24etc. indicated by the color red) were added. The 6th edition contained data onapproximately 2690 nuclides from 111 elements.

Revised 6th Edition, 1998/2001: the sixth edition was revised in 1999 to include data on the newly discovered element 112, new names for elements 104–108, new decay data for some transuranics and 150 mostly long-lived nuclides far from the line of stability.

UNIT 3
MASS DEFECT. BINDING ENERGY

Warm-up

Answer the following questions.

1. What is the mass defect?
2. What is the binding energy?
3. Would *E*=*mc*2 apply to all forms of energy?
4. Can you give examples how energy participates in gravitational forces?

Activity 1

Give definitions for the following nouns.

1. Ionization energy
2. Gravitational binding energy
3. Convention
4. Gravitational potential energy
5. Electromagnetic waves
6. Nuclear fusion

Reading

Binding energy is the mechanical energy required to disassemble a whole into separate parts. A bound system typically has a lower potential energy than its constituent parts; this is what keeps the system together—often this means that energy is released upon the creation of a bound state. The usual convention is that this corresponds to a positive binding energy.

In general, binding energy represents the mechanical work which must be done against the forces which hold an object together, disassembling the object into component parts separated by sufficient distance that further separation requires negligible additional work.

At the atomic level the atomic binding energy of the atom derives from 1 _______ and is the energy required to 2 _________ an atom into free electrons and a nucleus. Electron binding energy is a measure of the energy required to free electrons from their atomic orbits. This is more commonly known as ionization energy.[1]

At the nuclear level, binding energy is also equal to the energy liberated when a nucleus is created from other nucleons or nuclei.[2][3] This nuclear binding energy (binding energy of nucleons into a nuclide) is derived from the strong nuclear force and is the energy required to disassemble a nucleus into the same number of free unbound neutrons and protons it is composed of, so that the nucleons are far/distant enough from each other so that the strong nuclear force can no longer cause the particles to interact.[4]

In astrophysics, gravitational binding energy of a celestial body is the energy required to expand the material to infinity. This quantity is not to be confused with the gravitational potential energy, which is the energy required to separate two bodies, such as a celestial body and a satellite, to infinite distance, keeping each intact (the latter energy is lower).

In bound systems, if the binding energy is removed from the system, it must be subtracted from the mass of the unbound system, simply because this energy has mass, and if subtracted from the system at the time it is bound, will result in removal of mass from the system.[5] System mass is not conserved in this process because the system is not **closed** during the binding process.

Mass defect

The difference between the unbound system calculated mass and experimentally measured mass of nucleus is called mass defect. It is denoted by Δm. It can be calculated as follows:

Mass defect = (unbound system calculated mass) - (measured mass of nucleus)

i.e, (sum of masses of protons and neutrons) - (measured mass of nucleus)

In nuclear reactions, the energy that must be radiated or otherwise removed as binding energy may be in the form of electromagnetic waves, such as gamma radiation, or as heat. Again, however, no mass deficit can in theory appear until this radiation has been emitted and is no longer part of the system.

The energy given off during either nuclear fusion or nuclear fission is the difference between the binding energies of the fuel and the fusion or fission products. In practice, this energy may also be calculated from 3 ___________ differences between the fuel and products, once evolved heat and radiation have been removed.

When 4 _________ are grouped together to form a nucleus, they lose a small amount of mass, i.e., there is mass defect. This mass defect is released as (often radiant) energy according to the relation E = mc2; thus binding energy = mass defect × c2.

This energy is a measure of the forces that hold the nucleons together, and it represents energy which must be supplied from the environment if the nucleus is to be broken up. It is known as binding energy, and the mass defect is a measure of the binding energy because it simply represents the mass of the energy which has been lost to the environment after binding.

In 2005, Rainville published a direct test of the energy-equivalence of mass lost in the binding-energy of a neutron to atoms of particular isotopes of silicon and sulfur, by comparing the new mass-defect to the energy of the emitted 5 __________ associated with the neutron capture. The binding mass-loss agreed with the gamma ray energy to a precision of ±0.00004 %, the most accurate test of E=mc2 to date.[7] Binding energy is the mechanical energy required to disassemble a whole into separate parts. A bound system typically has a lower potential energy than its constituent parts; this is what keeps the system together—often this means that energy is released upon the creation of a bound state. The usual convention is that this corresponds to a positive binding energy.

The difference between the unbound system calculated mass and experimentally measured mass of nucleus is called mass defect. It is denoted by Δm. It can be calculated as follows:

Mass defect = (unbound system calculated mass) - (measured mass of nucleus)

i.e, (sum of masses of protons and neutrons) - (measured mass of nucleus)

In 6 __________, the energy that must be radiated or otherwise removed as binding energy may be in the form of electromagnetic waves, such as gamma radiation, or as heat. Again, however, no mass deficit can in theory appear until this 7 _________ has been emitted and is no longer part of the system.

The energy given off during either nuclear fusion or nuclear fission is the difference between the binding energies of the fuel and the fusion or fission products. In practice, this energy may also be calculated from the substantial mass differences between the fuel and products, once evolved heat and radiation have been removed.

When the nucleons are grouped together to form a nucleus, they lose a small amount of mass, i.e., there is mass defect. This mass defect is released as (often radiant) energy according to the relation E = mc2; thus binding energy = mass defect × c2.

This energy is a measure of the forces that hold the nucleons together, and it represents energy which must be supplied from the environment if the nucleus is to be broken up. It is known as binding energy, and the mass defect is a measure of the binding energy because it simply represents the mass of the energy which has been lost to 8 ___________ after binding.

In 2005, Rainville published a direct test of the energy-equivalence of mass lost in the binding-energy of a neutron to atoms of particular isotopes of silicon and sulfur, by comparing the new mass-defect to the energy of the emitted gamma ray associated with the neutron capture. The binding mass-loss agreed with the gamma ray energy to a precision of ±0.00004 %, the most accurate test of E=mc2 to date. [6]

Fill the gaps:

a. Gamma ray (5)
b. The substantial mass (3)
c. The nucleons (4)
d. Disassemble (2)
e. The environment (8)
f. Radiation (7)
g. Electromagnetic interaction (1)
h. Nuclear reactions (6)

Find synonyms in text:

1. Quantity *(measury)*
2. Emerge *(appear)*
3. reciprocal action *(interaction)*
4. even *(equal)*
5. unrein *(liberated)*

True or False:

1. Binding energy represents the mechanical work which must be done against the forces which hold an object together (T)
2. Electron binding energy is a measure of the energy required to free electrons from their atomic orbits (T)
3. The difference between the coupled system calculated mass and experimentally measured mass of nucleus is called mass defect. (F)
4. The energy given off during either nuclear fusion or nuclear fission is the compositions of the binding energies of the fuel and the fusion or fission products (F)

UNIT 4
RADIOACTIVE DECAY

TEXT 1

WARM UP

Work in pairs or groups. Before reading the text below, answer the question: What do you know about:

- Henri Becquerel

- Radioactive decay

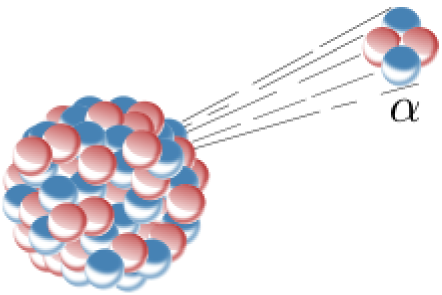
- Becquerel rays

Activity 1

Read the following text and do the tasks below (1-3):

Radioactive decay

Radioactive decay is the process by which an atomic nucleus of an unstable atom loses energy by emitting ionizing particles (ionizing radiation). The emission is spontaneous, in that the atom decays without any physical interaction with another particle from outside the atom. Usually, radioactive decay happens due to a process confined to the nucleus of the unstable atom, but, on occasion (as with the different processes of electron capture and internal conversion), an inner electron of the radioactive atom is also necessary to the process.



Alpha decay is one example type of radioactive decay, in which an atomic nucleus emits an alpha particle, and thereby transforms (or 'decays') into an atom with amass number 4 less and atomic number 2 less. Many other types of decays are possible.

Nuclides produced by radioactive decay are called radiogenic nuclides, whether they themselves are stable or not. There exist stable radiogenic nuclides that were formed from short-lived extinct radionuclides in the early solar system. The extra presence of these stable radiogenic nuclides (such as Xe-129 from primordial I-129) against the background of primordial stable nuclides can be inferred by various means.

Presently-radioactive nuclides are from three sources: many naturally-occurring radionuclides are short-lived radiogenic nuclides that are the daughters of ongoing radioactive primordial nuclides (types of radioactive atoms that have been present since the beginning of the Earth and solar system). Other naturally-occurring radioactive nuclides are cosmogenic nuclides, formed by cosmic ray bombardment of material in the Earth's atmosphere or crust. Finally, some primordial nuclides are radioactive, but are so long-lived that they remain present from the primordial solar nebula. For a summary table showing the number of stable nuclides and of radioactive nuclides in each category, see radionuclide.

Radioactivity was discovered in 1896 by the French scientist Henri Becquerel, while working on phosphorescent materials. During experiments to see if phosphorescent materials would expose photographic materials through black paper in the manner of the recently-discovered X-rays, which produced fluorescense, Becquerel used a phosphorescent uranium salt and eventually found that it blackened the plate through paper wrapping, in a desk drawer over a weekend, even without application of light, or production of its phosphorescence. These penetrating radiations, accidentally discovered emanating from uranium minerals, were first called Becquerel rays.

Activity 2

Complete the following sentences using the information from the text and your knowledge.

1. Radioactive decay is the process . . .

2. Radioactive decay happens due to . . .

3. Radioactivity was discovered in . . .

4. Some primordial nuclides are . . .

5. Other naturally-occurring radioactive nuclides are . . .

Activity 3

Work in pairs. Decide whether the statements below (1-3) are true or false. Correct the false sentences. Share your ideas with other students in your group.

1. Many naturally-occurring radionuclides are short-lived radiogenic nuclides that are the daughters of ongoing radioactive primordial nuclides.

2. Radioactivity was discovered in 1895 by the England scientist Henri Becquerel.

3. Some primordial nuclides are radioactive, but are so short-lived that they remain present from the primordial solar nebula.

Activity 4

Make a list of collocations with the words below.

Example: motion → molecular **motion, motion** of the fluid

Alpha nuclides rays stable particle Radioactive

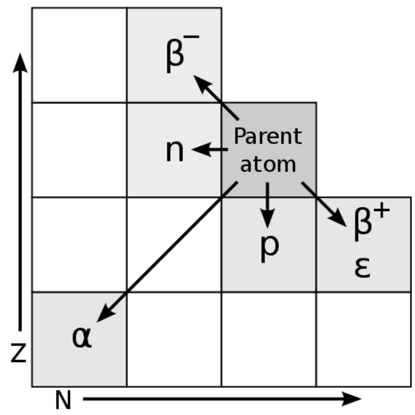
Types of decay

A) ...

In analyzing the nature of the decay 2.________, it was obvious from the direction of **electromagnetic forces** produced upon the radiations by external magnetic and electric fields that alpha rays carried a positive charge, beta rays carried a negative charge, and gamma rays were neutral. From the magnitude of deflection, it was clear that alpha particles were much more massive than beta particles. Passing alpha particles through a very thin glass window and trapping them in a discharge tube allowed researchers to study the emission spectrum of the resulting gas, and ultimately prove that alpha particles are helium nuclei. Other experiments showed the similarity between classical beta radiation and cathode rays: they are both streams of electrons. Likewise gamma radiation and X-rays were found to be similar high-energy electromagnetic radiation.

B) ...

Although alpha, beta, and gamma were found most commonly, other types of decay were eventually discovered. Shortly after the discovery of the positron in cosmic ray products, it was realized that the same process that operates in classical beta decay can also produce positrons (positron emission). In an analogous process, instead of emitting positrons and neutrinos, some proton-rich nuclides were found to capture their own atomic electrons (electron capture), and emit only a neutrino (and usually also a gamma ray). Each of these types of decay involves the capture or 6.________ of nuclear electrons or **positrons**, and acts to move a nucleus toward the ratio of neutrons to protons that has the least energy for a given total number of nucleons (neutrons plus protons).



Different types of decay of a radionuclide. Vertical: atomic number Z, Horizontal: neutron number N

Shortly after discovery of the neutron in 1932, it was discovered by Enrico Fermi that certain rare 7.________ reactions yield neutrons as a decay particle (neutron emission). Isolated proton emission was eventually observed in some elements. It was also found that some **heavy elements** may undergo spontaneous 8.________ into products that vary in composition. In a phenomenon called cluster decay, specific combinations of neutrons and protons (atomic nuclei) other than alpha particles (helium nuclei) were found to be spontaneously emitted from atoms, on occasion.

C) …

Rare events that involve a combination of two beta-decay type events happening simultaneously (see below) are known. Any decay process that does not violate conservation of energy or momentum laws (and perhaps other particle conservation laws) is permitted to happen, although not all have been detected. An interesting example (discussed in a final section) is bound state beta decay of rhenium-187. In this process, an inverse of electron 10.________, beta electron-decay of the parent nuclide is not accompanied by beta electron emission, because the beta particle has been captured into the K-shell of the emitting **atom**. An antineutrino, however, is emitted.

During alpha decay, the atomic nucleus releases an alpha particle. The nucleus will lose two protons and two neutrons when this happens. After the decay, the atom will change to another element, because the atom loses two protons. For example, if Americium were to go through alpha decay it would change into Neptunium because Neptunium is defined by having two protons fewer than Americium. Alpha decay usually happens in heavy elements, those containing more neutrons and protons, such as uranium, thorium, plutonium, and radium.

D) …

There are two kinds of beta decay, beta-plus and beta-minus.

In beta-minus decay, the nucleus gives out a negatively charged electron and a neutron changes into a proton:

$$n0 \to p+ + e- + \nu e.$$

where

n0 is the neutron;

p+ is the proton;

e- is the electron;

νe is the anti-neutrino.

Beta-minus decay happens in nuclear reactors.

In beta-plus decay, the nucleus releases a positron, which is like an electron but positively charged, and a proton changes into a neutron:

$$p+ \to n0 + e+ + \nu e.$$

where

p+ is the proton;

n0 is the neutron;

e+ is the positron;

νe is the neutrino.

Beta-plus decay happens inside the sun and in some types of particle accelerators.

E)…

Activity 5

Insert parts of the article 1)-4) in the text according to their meaning A)-E)

1) Alpha particles cannot even go through a few centimeters of air. Alpha irradiation cannot hurt humans when the alpha source is outside the human

body, because human skin does not let the alpha 11.________ go through. Alpha **radiation** can be very harmful if the source is inside the body, such as when people breathe dust or gas containing materials which decay by emitting alpha particles.

2) Other types of radioactive decay that emit previously seen particles were found, but by different mechanisms. An example is internal conversion, which results in electron and sometimes high-energy photon emission, even though it involves neither beta nor gamma decay. This type of decay (like isomeric transition gamma decay) did not transmute one 9.________ to another.

3) Gamma decay happens when a nucleus produces a high-energy 12.________ of energy called a gamma ray. Gamma rays do not have **electrical charge**, but they do have angular momentum. Gamma rays are usually emitted from nuclei immediately after other types of decay. Gamma rays can be used to analyze radioactive materials, to kill bacteria in food, to find some types of disease, and to treat some kinds of cancer. Gamma rays have the highest energy of any electromagnetic wave, and gamma ray bursts in space are the most energetic releases of energy known to people, even more than supernovas.

4) As for types of radioactive radiation, it was found that an electric or magnetic field could split such emissions into three types of beams. For lack of better terms, the rays were given the 1.________ names alpha, beta, and gamma, still in use today. While alpha decay was seen only in heavier elements (atomic number 52, tellurium, and greater), the other two types of decay were seen in all of the elements.

5) The 3.________ between types of decays also began to be examined: for example, gamma decay was almost always found associated with other types of decay, occurring at about the same time, or afterward. Gamma decay as a separate 4.________ (with its own **half-life**, now termed isomeric transition), was found in natural radioactivity to be a result of the gamma decay of excited 5.________ nuclear isomers, in turn created from other types of decay.

Activity 6

Read the text and fill in the blanks 1-12 words A-L.

a) emission;

b) packet;

c) products;

d) phenomenon;

e) element;

f) alphabetic;

g) relationship;

h) particles;

i) fission;

j) decay;

k) capture;

l) metastable.

Activity 7

Explain the meaning of selected words in the text.

UNIT 5.

RADIOACTIVITY

WARM UP

Work in pairs or groups. Before reading the text below, answer the question: What do you know about:

- Antoine Henri Becquerel
- Pierre Curie and Marie Curie
- Ernest Rutherford

Activity 1

You are going to read a text about the discovery of radioactivity. Five phrases have been removed from the text. Choose from the sentence A – F the one which fits each gap (1 – 5). There is one extra phrase, which you don't need to use.

A which governs the aggregation of matter
B was that a piece of mineral
C which he bombarded gold foil with particles (alpha particles) from a radioactive source
D which started with the exposure of a uranium-bearing crystal to sunlight
E the first person to win two Nobel Prizes
F they found that the ore was significantly more radioactive than the pure material

The Discovery of Radioactivity

One hundred years ago, a group of scientists unknowingly ushered in the Atomic Age. Driven by curiosity, these men and women explored the nature and functioning of atoms. Their work initiated paths of research which changed our understanding of the building blocks of matter; their discoveries prepared the way for development of new methods and tools used to explore our origins, the functioning of our bodies both in sickness and in health, and much more.

Antoine Henri Becquerel (1852-1908)

It was the month of February in the year of 1896. Antoine Henri Becquerel, a French scientist, was conducting an experiment **1**__________. Once the crystal had sat in the sunshine for a while, he placed it on a photographic plate. As he had anticipated, the crystal produced its image on the plate. Becquerel theorized that the absorbed energy of the sun was being released by the uranium in the form of x-rays.

Further testing of this theory had to be put off for a few days because the sky had clouded up and the sun had disappeared. For the next couple of days he left his sample of uranium in a closed drawer along with the photographic plate.

When the weather had cleared, he returned to the drawer to retrieve his gear. He was surprised to find that the crystal had left a clear, strong image on the photographic plate.

How could this be? There was no source of energy to produce the image! What Becquerel had discovered **2** _________ which contained uranium could produce it's image on a photographic plate in the absence of light. What he had discovered was radioactivity! He attributed this phenomenon to spontaneous emission by the uranium.

Pierre Curie (1859-1906), Marie Curie (1867-1934)

The husband and wife team of Pierre and Marie Curie became interested in Becquerel's discovery. While experimenting with their own uranium-containing ore, they came up with the term "radioactivity" to describe the spontaneous emissions that they studied.

While comparing the activity of pure uranium to a uranium ore sample, **3** _______. They concluded that the ore contained additional radioactive components besides the uranium. This observation led to the discovery of two new radioactive elements which they named polonium and radium.

Did you know this??

- In 1903, Becquerel and the Curies together received the Nobel Prize in physics. This award was for their discovery of radioactivity and their other contributions in this area.
- Marie Curie received a second Nobel Prize in 1911 for the discovery of polonium and radium. She was **4** _________.
- Did you know that the Curie's had a word named after them? That's right! The curie is a basic unit of measurement for describing radioactivity.

Ernest Rutherford (1871-1937)

The next important step down this road of discovery came from Ernest Rutherford. Among his many accomplishments was the fact that he named and characterized many aspects of radioactivity. He, therefore, developed the language that is in use today to describe radioactivity and atomic theory.

One cannot understand radioactivity without first understanding the atom. Rutherford's experiments, in **5** __________, led to the understanding of the atom. What he noted was that although most of the particles passed right through the gold foil, a very small percentage (approximately 1 in 8000) would "bounce back". What exactly did this imply?

He interpreted this to mean that matter was made up of mostly empty space, but there was a small dense portion of matter that deflected the particles. He defined this dense area as a nucleus surrounded by electrons at a great distance away from the nucleus. His discoveries led to our current understanding of the structure of the atom. In fact, Rutherford's planetary model of the atom is essentially what we use today.

Activity 2

Read the passage and decide if the sentences below are TRUE or FALSE? If one of them is TRUE put T next to it, if it's FALSE put F.

1. Henri Becquerel discovered radioactivity in 1896.
2. Marie Curie received a first Nobel Prize in 1911.
3. Rutherford interpreted his experiment to mean that matter was made up of mostly empty space, but there was a small dense portion of matter that deflected the particles.
4. Henri Becquerel discovered two new radioactive elements which he named polonium and radium.
5. Pierre and Marie Curie were brother and sister.

The Nuclear Radiation Quiz

1. What makes something radioactive?

- An unstable nucleus
- Elements with an atomic number higher than 83
- Haven't you seen any monster movies? Barrels of green toxic sludge!

2. Which of the following events would expose you to the most radiation?

- Living next to a nuclear power plant for a year
- Eating a banana
- Getting a CT scan of your chest

3. How does radioactive material generate electricity?

- The heat generated during fission creates steam that powers electricity generating turbines.
- The decay of uranium creates enough force to turn turbines directly.
- To quote Joe Dirt, "How exactly does the sun set? How exactly does the posi-trac rear end on a Plymouth work? It just does."

4. Which of the following typically poses the biggest health threat to humans?

- Alpha particles
- Beta particles
- Gamma rays

5. Which of the following household items might contain radioactive material?

- Smoke detectors
- Thermometers
- Hopefully none of them. Isn't that what a product recall is for?

6. How do you neutralize the radioactivity of a substance?

- Incinerate the material
- Run a high-voltage current through the material
- It can't be done.

7. What percentage of harmful gamma rays do the hazmat suits worn by nuclear technicians block?

- 30 percent
- 70 percent
- All of it

8. Who was the first person to discover radioactivity?

- Marie Curie
- Henri Becquerel
- Albert Einstein -- he pretty much discovered everything, right?

9. Where was the first nuclear reactor constructed?

- The Mojave Desert

- The Department of Defense's New York facility
- Under the bleachers of the University of Chicago's old football field

10. How long can the latest nuclear-powered submarines go without refueling?

- 10 years
- 20 years
- The life of the ship

11. How many nuclear power plants are there worldwide?

- A dozen
- Several hundred
- A few thousand

12. What are the symptoms of acute radiation syndrome?

- Nausea
- Blistering of the skin
- Loss of hair
- All of the above

13. What does the United States currently do with high-level nuclear waste generated from nuclear power plants?

- Stores the waste deep underground in the Yucca Mountain storage facility
- Places the waste in pools at the site where it's generated
- Sells the waste to companies and universities that then use it for medical and academic purposes

14. What does the term "half-life" mean in reference to radioactive material?

- The amount of time it takes for a radioactive atom to decay
- The amount of time it takes for half of a given sample of a radioactive material to decay
- Half-life? That's one of my all-time favorite computer games!

15. You're heading into an area where you know you'll be exposed to alpha radiation. What's the minimum amount of protection you'll need?

- You're kidding, right? I'm not going in there.

- One of those hazmat suits, I guess. Not very stylish, though.
- I'll just take my chances wearing jeans and a T-shirt.

16. What are nuclear physicists referring to when they mention the "island of stability"?

- The ideal conditions needed to keep radioactive materials from decaying
- The theoretical range of elements on the upper end of the periodic table where isotopes become stable again
- The island where nuclear physicists vacation after working too many long nights

17. How do workers at nuclear power plants know when they've received the maximum amount of radiation deemed safe?

- Workers rely on complex formulas that give them the number of minutes or hours they can spend in a given area.
- They use dosimeters that track the amount of radiation they've absorbed.
- Currently, there's no reliable way to track radiation exposure, so workers avoid dangerous areas altogether.

18. Which of the following isn't a real radioactive element?

- Rutherfordium
- Neptunium
- Vandammeium

19. Which of the following ISN'T true?

- The radioactive element polonium was used as a minor component of a toy bicycle in the 1950s.
- Before the first nuclear bomb was detonated, scientists took bets on whether or not it would destroy the entire world
- X-ray machines, used to aid the shoe fitting process, were once a fixture in shoe stores before the dangers of radiation were well-known.

20. Which of the following ISN'T a common, practical way we use nuclear radiation?

- Creating mutations in crops in an effort to cultivate beneficial traits

- Purifying drinking water contaminated by bacteria
- Carbon dating to figure out the age of ancient objects

UNIT 6

NEUTRON INTERACTIONS

READING

TEXT 1

WARM UP

Before reading the text below, answer the question basing on your knowledge: What do you know about:

a. discovery of the neutron;
b. neutron interactions;
c. fission.

Activity 1

Fill the gaps using the words below

a. spontaneously
b. scattering
c. fission
d. heavy
e. stable
f. neutrons

Neutron interactions

PART 1

Neutron Production

Neutrons can be created by the integration of an electron and a proton. Furthermore a free neutron will in time disintegrate into a proton and an electron. Neutrons interact with the nuclei of atoms in various ways and may also be produced by the nuclei of atoms. The most common source of neutrons is the fissioning process where a 1._____ nucleus splits into two lighter nuclei. This fissioning of nuclei and the subsequent interaction of the resultant 2._______ with other nuclei are the fundamental processes governing the production of power from nuclear energy. Knowledge of these processes is important in the study of nuclear engineering.

A heavy nucleus such as Uranium-235 will occasionally fission 3._____________ into two lighter nuclei. A heavy nucleus such as this has about one and a third as many neutrons as proton in its nucleus. Thus, when heavy nucleus fissions into two lighter nuclei, not as many neutrons are required to maintain a 4.______ configuration in the nucleus and some neutrons are emitted during the fission process.

In a nuclear reactor, fissile nuclei such as Uranium-235 and Plutonium-239 are introduced to 5.________ by having their nuclei exited beyond the level of stability. This is done by subjecting them to the influence of free neutrons. Free neutrons interact with various nuclei in different ways causing a range of different reaction of which fission is just one. Most interactions involve 6.___________ (non-absorption) or capture (absorption) of the neutrons and a transfer of energy. These reactions are important in maintaining and controlling the fission reactions in nuclear reactors.

Activity 2

Give definition to the following terms:

a) Neutron reaction –

b) Energy levels –

c) Radiative capture –

d) Scattering –

e) Fission –

f) Unstable nucleus –

Activity 3

Read the passage and decide if the sentences below are TRUE or FALSE? If one of them is TRUE put T next to it, if it's FALSE put F.

1. Neutrons interact with the nuclei of atoms only one way.
2. A heavy nucleus will occasionally fission spontaneously into two lighter nuclei.
3. Fissile nuclei are introduced to fission by having their nuclei exited beyond the level of instability.
4. Free neutrons interact with various nuclei in different ways.
5. Most interactions involve scattering of the neutrons and a transfer of energy.

Activity 4

Make sentences using word combinations:

1. Heavy nucleus.

2. Free neutrons.

3. Transfer of energy.
4. Nuclear reactor.
5. Stable configuration.

TEXT 2

Activity 5

Discuss these questions with your partner

1. What types of radiation does exist?
2. What particles can be emitted by nuclei?
3. What is the difference between elastic and inelastic scattering?

Activity 6

Read the text below and in groups define the words in bold.

Neutron interactions

PART 2

Elastic Scattering (Elastic Collision)

Elastic scattering occurs when a neutron strikes a nucleus and **rebounds** elastically. In such a **collision** kinetic energy is transmitted elastically in accordance with the basic laws of motion. If the nucleus is of the same mass as the neutron then a large amount of kinetic energy is transferred to the nucleus. If the nucleus is of a much greater mass than the neutron then most of the **kinetic energy** is retained by the neutron as it rebounds. The amount of kinetic energy transferred also depends upon the angle of impact and hence the direction of motion of the neutron and nucleus after the impact.

Inelastic Scattering (Inelastic Collision)

Inelastic scattering occurs when a neutron strikes and enters a nucleus. The nucleus is excited into an **unstable condition** and a neutron is immediately emitted but with a lower energy than that of the entering energy. The surplus energy is transferred to the nucleus as kinetic energy and excitation energy. The excited nucleus subsequently returns to the **ground state** by the emission of a γ-ray. Such collisions are inelastic since all the initial kinetic energy does not reappear as kinetic energy. Some is absorbed by the nucleus and subsequently emitted in a different form (γ-ray). The emitted neutron may or may not be the one that initially struck the nucleus. **In simplistic terms** the neutron can be considered simply to be bouncing off an energy absorbing nucleus.

Radiative Capture

Radiative capture can be considered to be similar to the initial process leading to inelastic scattering. A neutron strikes and enters a nucleus. The nucleus is excited but the level of excitation is insufficient to **eject** a neutron. Instead all the energy is transferred to the nucleus as kinetic energy and excitation energy. The excited nucleus subsequently returns to the ground by the emission of a **γ-ray**. The incoming neutron remains in the nucleus and the nuclide increases its number of neutrons by one. This is a very common type of reaction. It leads to the creation of heavier isotopes of the original element. Many of these may be radioactive and **decay** over time in different ways.

Activity 7

Explain the mechanism of the following neutron interactions:

a. Inelastic scattering

b. Inelastic scattering

c. Radiative capture

Activity 8

Read the passage and decide if the sentences below are TRUE or FALSE? If one of them is TRUE put T next to it, if it's FALSE put F.

1. The amount of kinetic energy transferred in an elastic scattering depends upon the angle of impact and hence the direction of motion of the neutron and nucleus after the impact.

2. An inelastic scattering occurs when a neutron strikes a nucleus and rebounds elastically.

3. In an inelastic scattering the surplus energy is transferred to the nucleus as kinetic energy and excitation energy.

4. A radiative capture a very uncommon type of reaction.

5. A radiative capture leads to the creation of heavier isotopes of the original element.

Activity 9

Match the notions and their definitions

a. Inelastic scattering	**1**. variants of a particular chemical element
b. Scattering	**2**. fundamental scattering process in which the kinetic energy of an incident particle is not conserved
c. Elastic scattering	**3**. general physical process where some forms of radiation are forced to deviate from a straight trajectory by one or more localized non-uniformities in the medium through which they pass
d. Isotope	**4**. fundamental scattering process in which the kinetic energy of the incident particles is conserved, only their direction of propagation is modified
e. Radiative capture	**5.** an elevation in energy level above an arbitrary baseline energy state
f. Excitation	**6**. a kind of nuclear reaction in which an atomic nucleus collides with one or more neutrons and they merge to form a heavier nucleus

TEXT 3

Activity 10

Answer the following questions:

What is a nuclear transmutation?

What is a neutron producing reactions?

What nuclei can undergo fission?

Activity 11

Before reading the text, decide in small groups (2-3 students) whether these statements are true or false using your knowledge of the subject. Then read the text and check your guesses.

1. In a nuclear transmutation the original element is changed or transmuted into a different element.

2. A neutron producing reactions occur when one additional neutrons are produced from a single neutron.

3. A neutron producing reaction is a common.

4. Fission is generally induced by neutrons.

5. In fission nucleus splits into two new mid-range nuclei usually of equal mass.

Neutron interactions

PART 3

Nuclear Transmutation (Charged Particle Reaction)

Nuclear transmutation is similar to radiative capture and inelastic scattering. A neutron strikes and enters a nucleus. The nucleus is excited into an unstable condition but a particle other than a neutron is emitted. The emitted particles are either protons or α-particles. This leaves the nucleus still in excited state and it subsequently returns to the ground state by the emission of a γ-ray. In this process the total number of protons in the nucleus is reduced by one for proton emission and by two for α-particle emission. The original element is thus changed or transmuted into a different element.

Neutron Producing Reaction

Neutron producing reactions occur when one or two additional neutrons are produced from a single neutron. As before a neutron strikes and enters a nucleus. The nucleus is excited into an unstable condition as with inelastic scattering but two or three neutrons instead of only one neutron are emitted. The still excited nucleus subsequently returns to its ground state by the emission of a γ-ray. This is an uncommon reaction occurring in only a few isotopes.

Fission

Although spontaneous fission occasionally occurs, fission is generally induced by neutrons. A neutron strikes and enters a heavy nucleus. The nucleus is excited into an unstable condition as with most of the foregoing interactions. In this unstable condition the nucleus splits into two new mid-range nuclei usually of unequal mass.

Since these new nuclei do not need as many neutrons for stability some neutrons are emitted immediately. The surplus binding energy drives the new nuclei (fission fragments) and neutron away one from another with high velocity. The new nuclei subsequently lose their kinetic energy by ionizing reactions with the surrounding nuclei through which they pass and return to their ground states by emission of γ-rays. They are invariably still unstable with too many neutrons and subsequently decay usually by β- particle and γ-ray emission. The high energy neutrons lose energy by scattering collisions with nuclei of the surrounding medium and are subsequently generally captured by other nuclei to produce one of the reactions described above.

Activity 12

Explain the mechanism of the following neutron interactions:

a. Nuclear transmutation

b. Neutron producing reactions

c. Fission

Activity 13

Choose the right answer

1. The emitted particles in are
   a. only protons
   b. only α-particles
   c. either protons or α-particles

2. In an neutron producing reaction excited nucleus subsequently returns to its ground state by the emission of:
   a. γ-ray
   b. α-particles
   c. β-particles

3. After the nucleus splits into two new nuclei some neutrons of these nuclei are emitted:

a. immediately

b. behind time

c. never

Activity 14

Write a summary to the text read.

UNIT 7

NUCLEAR FUEL CYCLE

Activity 1

Mining uranium

Uranium is the basic raw material of both civilian and military nuclear programs.

It is extracted from either open-cast pits or by underground mining. Although uranium occurs naturally all over the world, only a small fraction is found in concentrated ores.

When certain atoms of uranium are split in a chain reaction, energy is released. This process is called nuclear fission.

In a nuclear power station this fission occurs slowly, while in a nuclear weapon, very rapidly. In both instances, fission must be very carefully controlled.

Nuclear fission works best if isotopes - atoms with the same number of protons, but different numbers of neutrons - of uranium 235 (or plutonium 239) are used. These isotopes have almost identical chemical properties, but different nuclear properties. Uranium-235 is known as a "fissile isotope" because of its propensity to split in a chain reaction, releasing energy in the form of heat.

When a U-235 atom splits, it emits two or three neutrons. When other U-235 atoms are present, these neutrons collide with them causing the other atoms to split, producing more neutrons.

A nuclear reaction will only take place if there are enough u-235 atoms present to allow this process to continue as a self-sustaining chain reaction. This requirement is known as "critical mass".

However, every 1,000 atoms of naturally-occurring uranium contain only seven atoms of U-235, with the remaining 993 being denser U-238.

Activity 2

Explain the meaning of the following notions:

Open-cast pit, mining, fraction, ore, split, fission, isotope, collide, cause, critical mass

Conversion

Once extracted, uranium ore is taken to a mill to be crushed and ground into a fine powder. This is then purified in a chemical process and reconstituted in a solid form known as "yellow cake", due to its yellow coloring. Yellow cake consists of 60-70% uranium, and is radioactive.

The basic aim of nuclear scientists is to increase the amount of U-235 atoms, a process known as enrichment. To do this, the yellow cake is dissolved in nitric acid and chemically processed before being heated to become uranium hexafluoride gas.

Uranium hexafluoride is corrosive and reactive and must be handled very carefully. Pipes and pumps at conversion plants are specially constructed from aluminium and nickel alloys. The gas is also kept away from oil and grease lubricants to avoid any inadvertent chemical reactions.

Enrichment

The aim of enrichment is to increase the proportion of fissile uranium-235 atoms within uranium.

For uranium to work in a nuclear reactor it must be enriched to contain 2-3% uranium-235. Weapons-grade uranium must contain 90% or more u-235.

A common enrichment method is a gas centrifuge, where uranium hexafluoride gas is spun in a cylindrical chamber at high speeds. This causes the slightly denser isotope u-238 to separate from the lighter u-235.

The dense u-238 is drawn towards the bottom of the chamber and extracted; the lighter u-235 clusters near the centre and is collected.

The enriched u-235 is then fed into another centrifuge. The process is repeated many times through a chain of centrifuges known as a cascade.

The remaining uranium - essentially u-238 with all the u-235 removed - is known as depleted uranium. Depleted uranium, a heavy and slightly radioactive metal, is used as a component in armor-piercing shells and other munitions.

Another method of enrichment is known as diffusion.

This works on the principle that of the two isotopes present in uranium, hexafluoride gas, u-235 will diffuse more rapidly through a porous barrier than its heavier cousin, u-238.

As with the centrifuge method, this process must be repeated many times.

Answer the following questions.

What is “yellow cake”?

What is the main purpose of nuclear scientists?

What is enrichment?

What are the methods of enrichment?

Reactor

Nuclear reactors work on the principle that nuclear fission releases heat, which can be harnessed and used to heat water into steam to drive turbines.

A typical nuclear reactor uses enriched uranium in the form of fuel 'pellets', each roughly the size of a coin and about an inch long. The pellets are formed into long rods known as bundles, and housed inside a heavily insulated, pressurized chamber.

In many power stations, the bundles are submerged in water to keep them cool. Other types use carbon dioxide or liquid metal to cool the reactor core.

To function in a reactor – i.e. produce heat through a fissile reaction - the uranium core must be 'critical'. This means that the uranium must be in sufficiently enriched form to allow a self-sustaining chain reaction to occur.

To regulate this process, and allow the nuclear plant to function, control rods are inserted into the reactor chamber. The rods are made of a substance, typically cadmium, which absorbs neutrons inside the reactor.

Fewer neutrons mean fewer chain reactions are started, slowing down the fission process. There are more than 400 nuclear power stations across the globe, producing about 17% of the world's electricity. Nuclear reactors are also used to power submarines and naval vessels.

Activity 3

Find the English equivalents of the following sentences.

При ядерной реакции высвобождается тепло, которое может быть использовано, чтобы управлять турбинами.

В реакторе используется обогащенный уран в форме таблеток, размером примерно с монетку.

На многих атомных станциях сборки помещаются в воду, для охлаждения.

Чтобы производить тепло путем ядерной реакции ядро урана должно быть «критичным».

Бруски помещаются в камеру реактора.

На данный момент в мире насчитывается порядка 400 АЭС.

Reprocessing

Reprocessing is the chemical operation which separates useful fuel for recycling from nuclear waste.

Used fuel rods have their metallic outer casing stripped away before being dissolved in hot nitric acid. This produces uranium (96%), which is reused in reactors, highly radioactive waste (3%) and plutonium (1%).

All nuclear reactors produce plutonium, but military types produce it more efficiently than others.

A reprocessing plant and a reactor to produce sufficient plutonium could be housed inconspicuously in an ordinary-looking building.

This makes extracting plutonium by reprocessing an attractive option to any country wishing to pursue a clandestine weapons program.

Activity 4

Translate the paragraph from English into Russian.

Uranium bomb

The aim of all nuclear bomb designers is to create a supercritical mass which will sustain a chain reaction and violently release vast amounts of heat.

One of the simplest is a so-called 'gun' design.

Here, a smaller subcritical mass is fired at a larger one, causing the combined mass to go supercritical triggering a nuclear explosion.

The process occurs in less than a second.

To make fuel for a uranium bomb, highly-enriched uranium hexafluoride is first converted into uranium oxide, and then uranium metal ingots.

This can be done using relatively simple chemical and engineering processes.

The most powerful basic fission weapon - an atom bomb - will detonate with an explosion the force of 50 kilotons.

This force can be increased by a technique called boosting, which harnesses the properties of nuclear fusion.

Fusion consists of the joining together of the nuclei of atoms of hydrogen isotopes to produce nuclei of helium. This process occurs when hydrogen nuclei are subjected to intense heat and pressure, both of which are produced by a nuclear bomb.

Nuclear fusion has the effect of injecting more energetic neutrons into the fission reaction, resulting in a bigger explosion.

Such fission-fusion-fission devices are known as hydrogen bombs, or thermonuclear weapons.

Activity 5

Complete the sentences from the text using the following phrases. Translate the sentences into Russian.

supercritical mass……………………………………. violently release

subcritical mass…………………..…… triggering a nuclear explosion

fuel for a uranium bomb……………………….. uranium metal ingots

fission weapon………………………………………………. detonate

boosting…………………………………………………... harnesses

fusion consists…………………………………….. hydrogen isotopes

fission-fusion-fission…………………………….……………. bombs

Plutonium bomb

Plutonium offers several advantages over uranium as a component in a nuclear weapon. Only about 4kg of plutonium is needed to make a bomb. Such a device would explode with the power of 20 kilotons.

To produce 12kg of plutonium per year, only a relatively small reprocessing facility would be needed.

A warhead consists of a sphere of plutonium surrounded by a shell of material such as beryllium, which reflects neutrons back into the fission process.

This means that less plutonium is needed to achieve critical mass, and produce a self sustaining fission reaction.

A terrorist group or country may find it easier to acquire plutonium from civil nuclear reactors, rather than enriched uranium, to produce a nuclear explosive.

Experts believe a crude plutonium bomb could be designed and assembled by terrorists possessing no greater level of skill than needed by the AUM cult to attack the Tokyo underground with nerve gas in 1995.

A nuclear explosive of this nature could explode with the power of 100 tones of TNT - 20 times more powerful than the largest terrorist bomb attack to date.

Activity 6

Match the words and phrases with their definitions.

1. advantage	a. a round solid figure, or its surface, with every point on its surface equidistant from its centre
2. weapon	b. burst or shatter violently and noisily as a result of rapid combustion, excessive internal pressure, or other process
3. plutonium	c. obtain
4. device	d. the hard protective outer case
5. explode	e. gather together in one place for a common purpose
6. reprocessing facility	f. a series of actions or steps taken in order to achieve the action of dividing or splitting something into two or more parts
7. sphere	g. in a natural or raw state; not yet

	processed or refined
8. shell	h. a condition or circumstance that puts one in a favorable or superior position
9. neutron	i. a set up establishment relating to the treatment of materials in order to make them reusable
10.fission process	j. the chemical element of atomic number 94, a dense silvery radioactive metal of the actinide series, used as a fuel in nuclear reactors and as an explosive in nuclear fission weapons.
11.reaction	k. improve or enhance the quality or value
12.acquire	l. a subatomic particle of about the same mass as a proton but without an electric charge, present in all atomic nuclei except those of ordinary hydrogen
13.civil	m. a thing designed or used for inflicting bodily harm or physical damage
14.enrich	n. relating to ordinary citizens and their concerns, as distinct from military or ecclesiastical matters
15.assemble	o. a response to some stimulus
16.crude	p. a thing made or adapted for a particular purpose, esp. a mechanical or electronic contrivance

UNIT 8

TYPES OF NUCLEAR REACTORS

"Environmentalists have long been fond of saying that the sun is the only safe nuclear reactor, situated as it is some ninety-three million miles away."
Stephanie Mills

WARM-UP

Here is the list of different types on nuclear reactors. Match them with the countries they are used in. More than one country can be applicable to a reactor type. You are welcome to use Internet as much as you need. You can find out that the nuclear reactor typology can be controversial.

USA, France, Japan, India

former Soviet Union, United Kingdom

Germany, Canada, South Africa, China

1. Pressurized Water Reactors (PWR)
2. Boiling Water Reactors (BWR)
3. Pressurized Heavy Water Reactor (PHWR)
4. Reaktor Bolshoy Moschnosti Kanalniy (High Power Channel Reactor) (RBMK)
5. Advanced Gas Cooled Reactor (AGR)
6. Liquid Metal Fast Breeder Reactor (LMFBR)
7. Pebble Bed Reactors (PBR)
8. Molten Salt Reactors (MSR)
9. Aqueous Homogeneous Reactor (AHR)
10. Liquid-Metal Fast-Breeder Reactor (LMFBR)
11. Magnox reactor – United Kingdom
12. CANada Deuterium Uranium Reactor (CANDU)

What do you think are the reasons of using a particular nuclear reactor type by a country?

PRE-READING

Activity 1. Look through the list on the nuclear reactor parts. What functions do they have?

- ***Turbine***
- ***Coolant***
- ***Moderator***
- ***Condenser***
- ***Control rods***

Activity 2. Here are the proper names. Why are they used within the context of nuclear reactors?

Albert Einstein, Leó Szilárd, Franklin D. Roosevelt, Chicago Pile

Activity 3. Read the text, make sure your guesses for pre-reading activities were correct and do the comprehension tasks below.

NUCLEAR REACTORS

A nuclear reactor is a device to initiate and control a sustained nuclear chain reaction. Most commonly they are used for generating electricity and for the propulsion of ships. Usually heat from nuclear fission is passed to a working fluid (water or gas), which runs through turbines that power either ship's propellers or generators. Some produce isotopes for medical and industrial use, and some are run only for research. Just as conventional power stations generate electricity by harnessing the thermal energy released from burning fossil fuels, nuclear reactors convert the thermal energy released from nuclear fission.

Early reactors

The neutron was discovered in 1932. The concept of a nuclear chain reaction brought about by nuclear reactions mediated by neutrons, was first realized shortly thereafter, by Hungarian scientist Leó Szilárd, in 1933. He filed a patent for his idea of a simple nuclear reactor the following year while working at the Admiralty in London. However, Szilárd's idea did not incorporate the idea of nuclear fission as a neutron source, since that process was not yet discovered. Szilárd's ideas for nuclear reactors using neutron-mediated nuclear chain reactions in light elements proved unworkable.

Inspiration for a new type of reactor using uranium came from the discovery by Lise Meitner, Fritz Strassman and Otto Hahn in 1938 that bombardment of uranium with neutrons (provided by an alpha-on-beryllium fusion reaction, a "neutron howitzer") produced a barium residue, which they reasoned was created by the fissioning of the uranium nuclei. Subsequent studies in early 1939 (one of them by Szilárd and Fermi) revealed that several neutrons were also released during the fissioning, making available the opportunity for the nuclear chain reaction that Szilárd had envisioned six years previously.

On August 2, 1939 Albert Einstein signed a letter to President Franklin D. Roosevelt (written by Szilard) suggesting that the discovery of uranium's fission could lead to the development of "extremely powerful bombs of a new type", giving impetus to the study of reactors and fission. Szilárd and Einstein knew each other well and had worked together years previously, but Einstein had never thought about this possibility for nuclear energy until Szilard reported it to him, at the beginning of his quest to produce the Einstein-Szilard letter to alert the U.S. government.

Shortly after, Hitler's Germany invaded Poland in 1939, starting World War II in Europe. The U.S. was not yet officially at war, but in October, when the Einstein-Szilard letter was delivered to Roosevelt, he commented that the purpose of doing the research was to make sure "the Nazis don't blow us up." The U.S. nuclear project followed, although with some delay as there remained skepticism (some of it from Fermi) and also little action from the small number of officials in the government who were initially charged with moving the project forward.

The following year the U.S. Government received the Frisch–Peierls memorandum from the UK, which stated that the amount of uranium needed for a chain reaction was far lower than had previously been thought. The memorandum was a product of the MAUD Committee, which was working on the UK atomic bomb project, known as Tube Alloys, later to be subsumed within the Manhattan Project.

Eventually, the first artificial nuclear reactor, Chicago Pile-1, was constructed at the University of Chicago, by a team led by Enrico Fermi, in late 1942. By this time, the program had been pressured for a year by U.S. entry into the war. The Chicago Pile achieved criticality on December 2, 1942 at 3:25 PM. The reactor support structure was made of wood, which supported a pile (hence the name) of graphite blocks, embedded in which was natural uranium-oxide 'pseudospheres' or 'briquettes'.

Soon after the Chicago Pile, the U.S. military developed a number of nuclear reactors for the Manhattan Project starting in 1943. The primary purpose for the largest reactors (located at the Hanford Site in Washington state), was the mass production of plutonium for nuclear weapons. Fermi and Szilard applied for a patent on reactors on 19 December 1944. Its issuance was delayed for 10 years because of wartime secrecy.

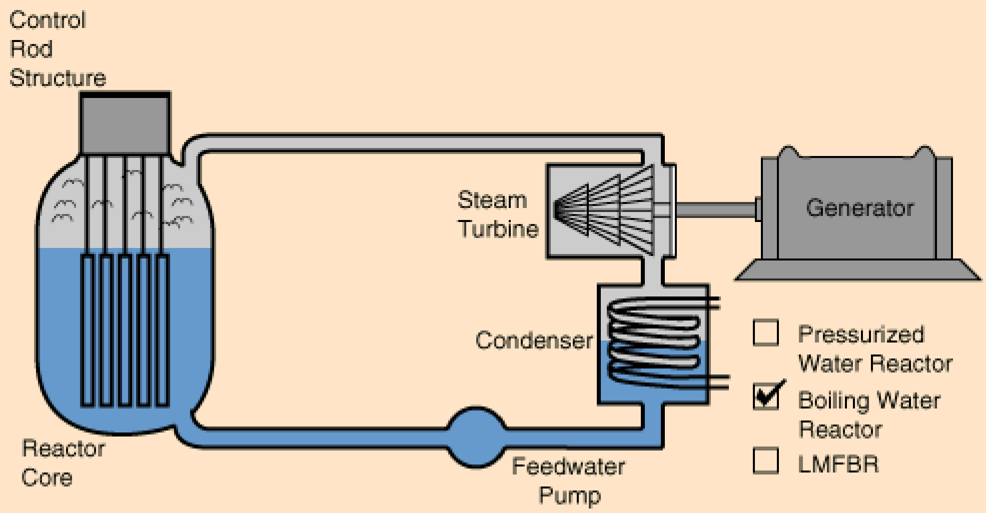
"World's first nuclear power plant" is the claim made by signs at the site of the EBR-I, which is now a museum near Arco, Idaho. This experimental LMFBR operated by the U.S. Atomic Energy Commission produced 0.8 kW in a test on December 20, 1951 and 100 kW (electrical) the following day, having a design output of 200 kW (electrical).

Besides the military uses of nuclear reactors, there were political reasons to pursue civilian use of atomic energy. U.S. President Dwight Eisenhower made his famous Atoms for Peace speech to the UN General Assembly on December 8, 1953. This diplomacy led to the dissemination of reactor technology to U.S. institutions and worldwide. The first nuclear power plant built for civil purposes was the AM-1 Obninsk Nuclear Power Plant, launched on June 27, 1954 in the Soviet Union. It produced around 5 MW (electrical).

After World War II, the U.S. military sought other uses for nuclear reactor technology. Research by the Army and the Air Force never came to fruition; however, the U.S. Navy succeeded when they steamed the USS *Nautilus* (SSN-571) on nuclear power January 17, 1955. The first commercial nuclear power station, Calder Hall in Sellafield, England was opened in 1956 with an initial capacity of 50 MW (later 200 MW). The first portable nuclear reactor "Alco PM-2A" used to generate electrical power (2 MW) for Camp Century from 1960

Boiling Water Reactor

In the boiling water reactor the same water loop serves as moderator, coolant for the core, and steam source for the turbine.

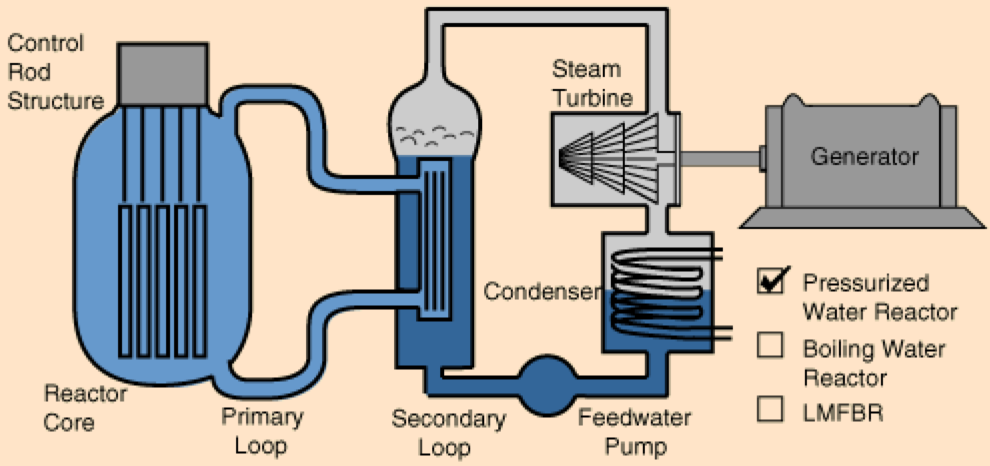


The water which passes over the reactor core to act as moderator and coolant is also the steam source for the turbine. The disadvantage of this is that any fuel leak might make the water radioactive and that radioactivity would reach the turbine and the rest of the loop.

A typical operating pressure for such reactors is about 70 atmospheres at which pressure the water boils at about 285ŸC. This operating temperature gives a Carnot efficiency of only 42% with a practical operating efficiency of around 32%, somewhat less than the PWR.

Pressurized Water Reactor

In the pressurized water reactor, the water which flows through the reactor core is isolated from the turbine.



The water which passes over the reactor core to act as moderator and coolant does not flow to the turbine, but is contained in a pressurized primary loop. The primary loop water produces steam in the secondary loop which drives the turbine. The obvious advantage to this is that a fuel leak in the core would not pass any radioactive contaminants to the turbine and condenser.

Another advantage is that the PWR can operate at higher pressure and temperature, about 160 atmospheres and about 315 C. This provides a higher. Carnot efficiency than the BWR, but the reactor is more complicated and more costly to construct. Most of the U.S. reactors are pressurized water reactors.

Pressurized Heavy Water Reactors (PHWRs)

In 2008, there were 27 pressurized heavy water reactors (PHWRs) operating worldwide in six countries, of which 17 are in their country of origin, Canada. The remainder of the world's PHWRs can be found in Argentina, India, Pakistan, the Republic of Korea and Romania. Known as CANDU (CANadian Deuterium Uranium) reactors, they use heavy water (D2O, water formed with the heavier deuterium isotope of hydrogen), as both coolant and moderator.

Heavy water allows natural uranium to be used as fuel, thereby eliminating the need, and cost, to enrich the uranium. On the other hand, the production of heavy water requires a dedicated plant to separate the D2O from ordinary water, raising the concentration of D2O from much less than 1% in its natural state to 99% in a CANDU reactor. As in a PWR, the coolant is passed through a steam generator so as to boil ordinary water in a separate loop. An advantage of the CANDU design is that refuelling can take place during operation, whereas pressurized water reactors (PWRs) and boiling water reactors (BWRs) must shut down in order to refuel. This feature allows high availability but also increases the complexity of operation.

Gas-Cooled Reactors (GCR)

Gas-cooled reactors are only in use in the United Kingdom. There are two types, the Magnox (named from the magnesium alloy used to clad the fuel elements) and the advanced gas-cooled reactor (AGR). Both use carbon dioxide as the coolant and graphite as the moderator. The Magnox uses natural uranium as fuel and the AGR, enriched uranium. Like CANDU reactors, these designs can be refuelled on-line, with the same characteristics as stated above.

RBMK

The name is a Russian acronym meaning large power boiling reactor. Ordinary water is used as the coolant and graphite as the moderator. As with a BWR, the coolant boils as it passes through the reactor and the resultant steam is passed directly to turbine generators. As an early design, the RBMK was often built, and some are operated, without the safety characteristics and features required elsewhere. The well-known accident at Chernobyl (Ukraine) in 1986 happened to a reactor of this type. RBMKs are the object of special safety concerns because they cannot be upgraded to correspond to contemporary safety practices at reasonable cost.

Fast Breeder Reactors

The reactor types described above are thermal reactors, most of the fission being caused by thermal neutrons. Fast reactors are designed so as to make use of fast neutrons with much higher kinetic energies. Fast reactors release more neutrons per fission than thermal reactors, and make better use of them because the relative probability of neutron capture (compared with fission) decreases at higher neutron energies. These excess neutrons can be used to convert fertile materials, for example uranium-238 (238U) and thorium-232 (232Th), into fissile materials through neutron capture. This newly created fissile material can in turn fuel the reactor. It is possible to design reactors to produce more fuel than they consume in breeder reactors. Typically, breeder reactors are fast reactors, though designs exist that could use thermal neutrons. Fast breeder reactors, by creating fuel from non-fissile isotopes and improving the efficiency of utilization through recycling, can potentially increase available world nuclear fuel resources up to 50-fold and are therefore a key element in the sustainability of nuclear energy in the very long term. Breeder reactors have been built and operated in a number of countries, though in 2002 they were operated only in France, India, Japan and the Russian Federation.

http://hyperphysics.phy-astr.gsu.edu/hbase/nucene/reactor.html
http://en.wikipedia.org/wiki/Nuclear_reactor

COMPREHENSION

Activity 4. Answer the following questions to the text

1. How does a nuclear reactor function? What integral parts does any nuclear reactor have? Answer the questions as if you explain this to a non-professional.
2. Who was the first to invent the nuclear reactor?
3. What discoveries were helpful in nuclear reactor design?
4. What happens to U 235 atom in the reactor? Explain the essence of its "adventure"
5. According to you, how is it possible to improve the efficiency of nuclear reactors? Do you know anything about the efforts of scientists to do that?

Activity 5. Fill in the following table with the information from the text

Type of reactor	Coolant	Fuel	Moderator	Advantages	Disadvantages
Fast Breeder Reactors					
RBMK					
Gas-Cooled Reactors					

Pressurized Heavy Water Reactors					
Boiling Water Reactors					
VVER					
Pressurized Water Reactors					

Name a distinctive feature of each nuclear reactor type

Activity 6. Jeopardy! is an American television quiz show featuring trivia in history, literature, the arts, pop culture, science, sports, geography, wordplay, and other topics. The show has an answer-and-question format in which contestants are presented with clues in the form of answers, and must phrase their responses in question form. Divide into 2 teams. Each team thinks of 5 answers (clues) to the other team to make up a question (answer).

Example: Team A *clue* – the PWR can operate at a higher pressure and temperature
Team B *answer* – What are the advantages of PWR?

LANGUAGE PRACTICE

Activity 7. Jigsaw puzzle. Find 20 words from "Essential Vocabulary to the text"

S	T	V	G	H	A	D	O	P	R	I	M	K	B	O	P	D	N	M	A
A	H	D	U	N	W	O	R	K	A	B	L	E	V	R	F	O	P	R	L
T	E	N	E	U	T	R	O	N	C	A	P	T	U	R	E	U	I	J	E
G	R	V	E	E	T	R	W	O	H	K	L	P	N	M	A	C	E	W	R
C	E	U	N	U	C	L	E	A	R	F	I	S	S	I	O	N	N	E	T
V	A	N	M	A	T	Y	U	G	J	F	L	P	E	Q	L	P	Y	U	D
Z	F	D	O	W	R	V	G	U	K	I	A	R	P	N	M	O	P	R	B
G	T	M	E	D	I	A	T	E	N	S	D	G	S	H	O	R	T	L	Y
H	E	E	R	T	Y	N	M	N	P	S	D	S	C	O	P	N	I	N	E
N	R	P	A	S	S	O	V	E	R	I	E	X	C	O	P	R	T	R	R
N	W	E	R	T	U	F	D	B	N	L	M	V	M	G	R	P	K	L	E
O	N	M	G	J	K	S	A	Q	w	E	R	T	Y	H	U	I	J	K	A
P	G	Q	I	M	O	D	E	R	A	T	O	R	B	O	C	M	N	I	S
R	V	D	F	R	T	Y	Q	I	W	A	T	E	R	L	O	O	P	L	O

E	S	U	B	S	E	Q	U	E	N	T	G	H	D	P	O	G	A	S	N
F	V	X	Z	A	Q	F	Y	Q	P	A	F	G	J	K	L	O	P	E	E
U	V	B	R	T	U	R	B	I	N	E	F	G	P	H	A	V	J	M	L
E	S	H	U	T	D	O	W	N	G	E	W	Q	Y	R	N	R	W	Q	K
L	R	E	A	C	T	O	R	C	O	R	E	J	K	L	T	M	N	F	T
F	H	O	P	T	C	O	N	D	E	N	S	E	R	Y	H	J	K	I	O

Activity 8. Divide into pairs. Choose 10 words from the Activity 7 and explain their meaning to your partner so that he/she could guess what they mean.

LISTENING AND SPEAKING

Activity 9. Discuss the following questions in the groups:

- Do you know the reasons for Fukushima Daichi disaster in Japan?
- Do you have any ideas how to avoid the drawbacks in current nuclear reactor design to prevent a disaster?

Activity 10. Previewing the vocabulary. Match the key video phrases with their explanations.

1. Utility	A mechanical system whereby an article is conveyed through sites at which successive operations are performed on it
2. Intervention	B diminish gradually in energy, intensity, or scope
3. Back up (system)	C deteriorate, make worse
4. Assembly line	D a company that performs a public service
5. Escalate (v)	E reserve or substitute
6. Withstand (v)	F actions provided to improve a situation
7. Wind down	G resist or endure successfully

Activity11. ***Watch the video on new designs for Nuclear Reactors http://www.youtube.com/watch?v=OB1KVXm53v0 and identify the context for the a) expressions in the Activity 9; b) following precise information***

- AP1000
- Scana
- China
- Toshiba Westing house Unit
- Georgia, South Carolina

Activity 12. Watch the video again. Divide into 2 teams. Team A answers the question "What is going to be new and more effective in nuclear reactor design?" Team B catch the information on what is supposed to be obsolete (not that effective) in nuclear reactors.

Activity 13. Imagine, some organization is about to invest money into the scientific program of nuclear technologies development.

Choose a person from your group who is going to be an investor. Divide into 2 teams. The first one would agitate for big industrial reactors. The second one will be for small reactor types. The investor's responsibility is to decide whose project gets funding depending on the reasons the teams provide. Use tips on getting investor's attention from the EFFECTIVE PRESENTATION section below.

EFFECTIVE PRESENTATION

Getting started!

There are three main ways to **give an effective presentation**:

✓ *Dealing with your fear*

✓ *Knowing your audience*

✓ *Getting and keeping the attention of the audience*

Deal with your fear!!!

Genius is 1% inspiration and 99% perspiration – Thomas Edison

- Accept your fear.

- You are not alone.

- Start to manage your fear: acknowledge and accept the fear as something that is hard-wired in all of us. In fact, new research into cognitive development finds that you would be abnormal if you experienced no anxiety at all. “Instead of trying to eradicate the fear response, a more reasonable approach,” says Berns, “is to examine the situations that set it off and try to inhibit it.”

- Reframe your fear. One of the situations that sets off public speaking fear is negative self talk. Replace negative emotions with positive ones. “If someone consistently perceives public speaking as an unpleasant event, the brain will default to this interpretation,” says Berns.

- Control your fear. The secret is practice. Lots of it.

Know your audience!!!

- Analyze your audience. Know what it wants. Know what it needs. Mingle beforehand if possible.
- What keeps them up at night?
- How can you solve their problem?
- How can you reach them? Have something for everyone.
- How will your audience resist?

Get and keep the attention of the audience!!!

Your first words are critical

“The first 25 words you speak are the most important ones of your message.
Here are some of the most commonly used methods for successfully getting and keeping audience attention.

1. Ask a question.

You can ask a rhetorical question or something that involves everyone by getting him or her to think about the topic.

*2**. State an impressive fact.***

Begin with a shocking, unusual or impressive fact connected to the theme of your presentation.

3. Tell a story.

Telling a personal story closely connected to the theme of your presentation is a great way to begin. People usually like to hear personal stories, which are not too long or try to glorify the narrator too much.

4. Cite a quotation.

Quotations are much used for presentations and they add a colourful touch to your personal style.

5. Tell a joke.

Jokes are wonderful for relaxing the audience and setting a cheerful mood. Relaxed audiences tend to be more interactive. This might make the presenters work somewhat easier.

The joke must be appropriate.

6. Get close to the audience.

Disturb the comfort zone of the audience by walking closer or going absolutely to one side.

USEFUL PHRASES TO START A PRESENTATION

Today I'm going to talk about...
In this presentation, I'd like to tell you a little bit about...

So, how much do you know about ___________?
Have you ever asked yourself why ... ?
What I'm going to tell you about today will change the way you think about...
Pass around the picture/object. What do you think it is?

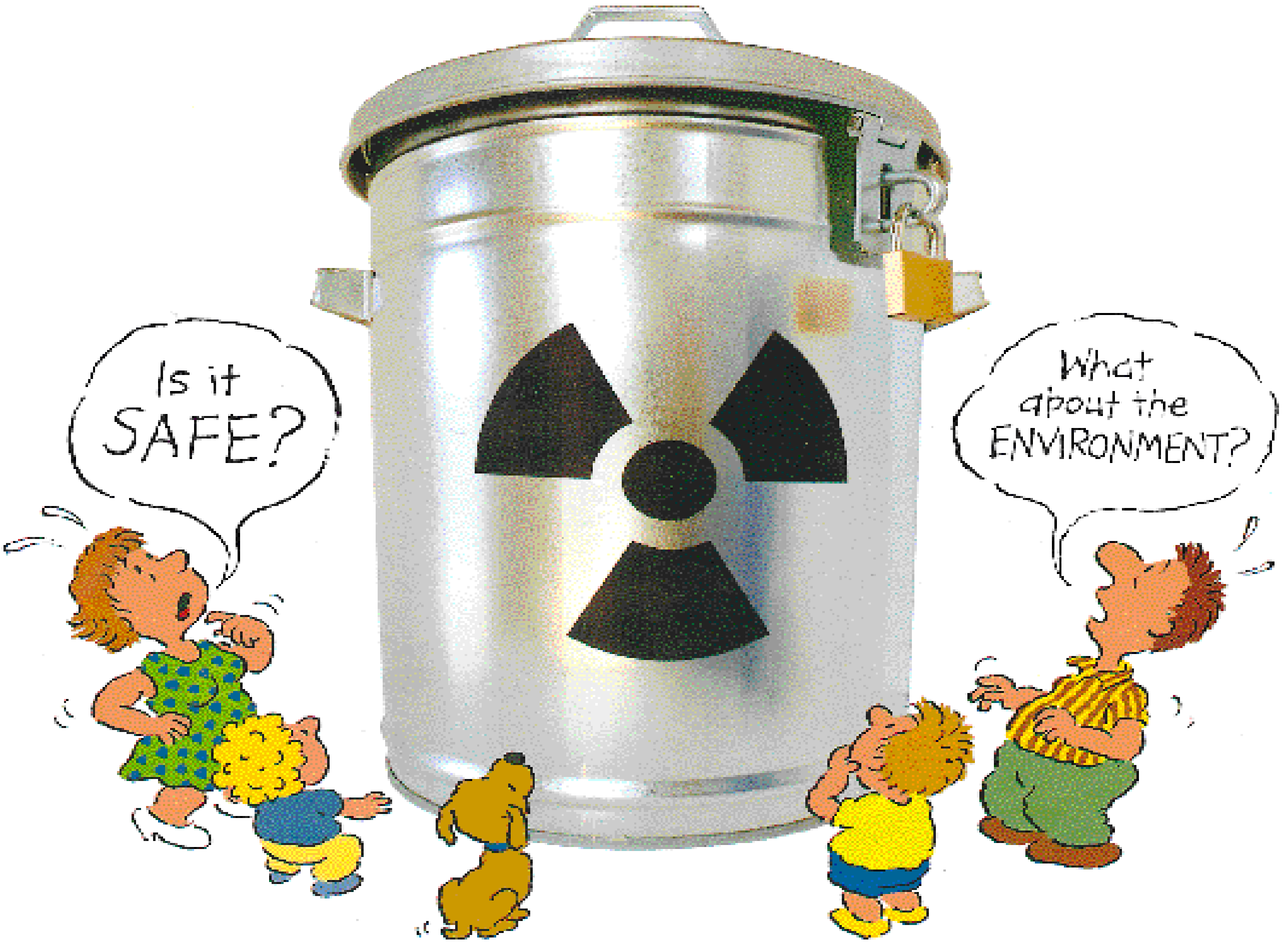
http://englishfornuclearsecurity.wordpress.com/2012/06/

ESSENTIAL VOCABULARY

1. Nuclear chain reaction
2. Generate electricity
3. Propulsion of ships
4. Nuclear fission
5. Medical and industrial use
6. To be run for research
7. Mediate (v)
8. Shortly
9. Thereafter
10. File a patent
11. Unworkable
12. Residue
13. Reason (v)
14. Subsequent
15. Give an impetus
16. Alert (v)
17. Move smth forward
18. Artificial nuclear reactor
19. Primary purpose
20. Wartime secrecy
21. Design output
22. Dissemination of reactor technology
23. Come to fruition
24. Water loop
25. Moderator
26. Coolant
27. Pass over (v)
28. Reactor core
29. Carnot efficiency
30. Turbine
31. Condenser
32. Country of origin
33. Eliminate the need
34. Ordinary water
35. Refuel
36. Shut down
37. Graphite
38. Safety characteristics
39. At reasonable cost
40. Make use of smth
41. Neutron capture
42. Fertile materials
43. Fissile
44. Non-fissile isotops
45. Sustainability
46. Utility
47. Interventions
48. Back up system
49. Assembly line
50. Escalate (v)
51. Wind down
52. Withstand

UNIT 9
NUCLEAR SAFETY

For safety is not a gadget but a state of mind.
~Eleanor Everet



WARM-UP

Look through these sayings on Safety by an unknown author. What idea do they convey? What is your idea of Safety?

- Don't learn safety by accident.
- Safety doesn't happen by accident.
- Safety…Did it, done it, doing it tomorrow
- Safety is no accident

PRE-READING

Activity 1. Look through the definition of Safety. How would you change it to fit the definition of Nuclear Safety more? What aspects would you add?

Safety is the state of being "safe" (from French *sauf*), the condition of being protected against physical, social, spiritual, financial, political, emotional, occupational, psychological, educational or other types or consequences of failure, damage, error, accidents, harm or any other event which could be considered non-desirable. Safety can also be defined to be the control of recognized hazards to achieve an acceptable level of risk. This can take the form of being protected from the event or from exposure to something that causes health or economical losses. It can include protection of people or of possessions.

http://en.wikipedia.org/wiki/Safety

NUCLEAR SAFETY

Activity 2. Scan the text and match the headings with the parts of the text. One heading is an extra one.

1. Comprehensive testing
2. Operating experience
3. Safety assessment
4. Siting
5. Basic elements of nuclear safety
6. Robust and proven design
7. Engineered safety system
8. Safety aspects of future reactors
9. Oversight and regulations
10. High-quality manufacturing and construction
11. Sound operating practices

The safety of a nuclear facility depends on the engineered protection built into it and on the organisation, training, procedures and attitudes of the operators. The basic design philosophy underpinning the safety of nuclear facilities is defence in depth, a key aspect being the provision of several layers of protection against the release of radioactivity, each providing backup if another fails. Nuclear energy has the potential to cause damage to people and to the environment through the accidental escape of harmful radioactive substances. Very high levels of safety have therefore always been considered essential to its deployment. There nevertheless remains some degree of risk, however slight, as with numerous other human endeavours.

Nuclear energy installations, whether they be nuclear power plants, reprocessing or waste conditioning plants or spent fuel storage facilities, typically involve large amounts of radioactivity whose release could produce radioactive contamination of the environment and be injurious to people's health. The primary purpose of all nuclear safety measures is thus to ensure that radioactivity remains in all circumstances contained or, if released, then only in amounts and under controls that ensure no significant harm is done.

In general terms, then, the safety of a nuclear installation can be understood as the ability of the installation's systems and its personnel to prevent accidents from occurring, or should one occur, to mitigate its consequences to a minimum. Ultimately, the radiological impact on people and the environment resulting from operating nuclear installations must be as small as possible for both normal operation and potential accidents. To achieve this objective, or in other words to ensure that the installation is considered sufficiently safe, technical and organisational measures are put in place at all stages of a nuclear facility's lifetime: starting with its siting and design; its manufacturing, construction and commissioning; during operation; and finally its decommissioning.

A_______________

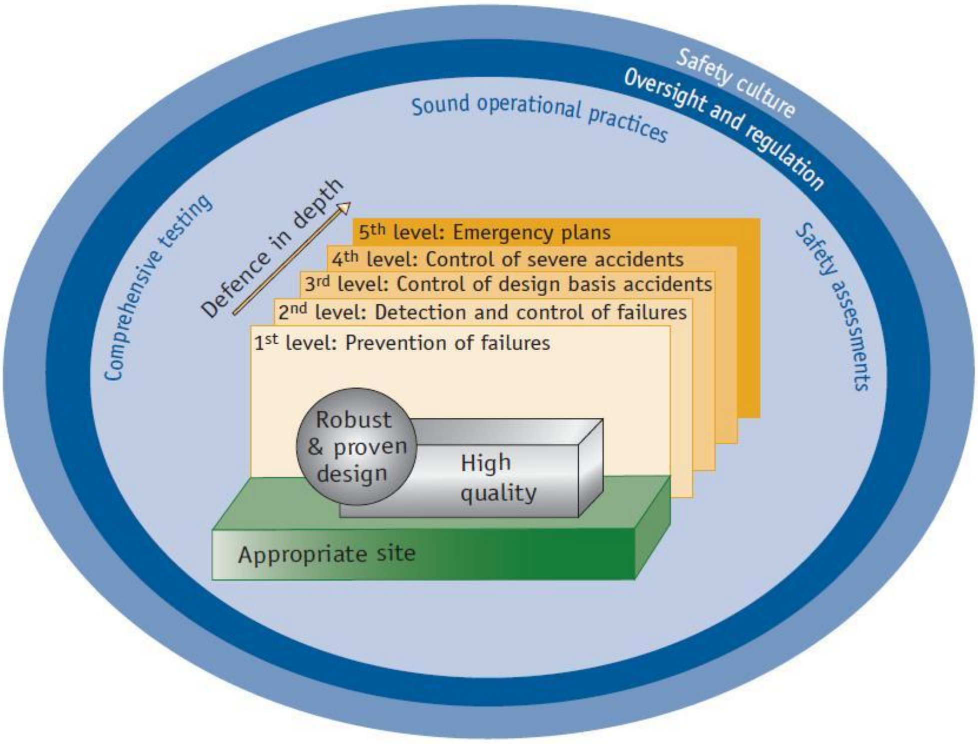


Figure 5.1: Elements of nuclear safety

Nuclear safety is achieved as a result of a number of complementary and overlapping factors (see Figure 5.1):

● detailed attention from the outset to all the factors that bear upon the safety of a planned installation, viz, its siting, its robust and proven design, high quality manufacturing and construction, and comprehensive testing prior to operation;

● ensuring that the probability of plant failures is low and considered in plant design, and that multiple protections are provided to prevent any particular fault or failure resulting in an accident (a concept known as defence in depth);

● close attention to the human element through sound operational practices and management systems that include performing periodic safety assessments and that foster the safety culture of the operating and regulatory organisations;

● monitoring and inspection by an independent regulatory authority with powers to suspend operations, or in the last resort to withdraw a licence.

These concepts lead to the practical arrangements summarised below.

B___________

The selection of a site for a nuclear power station (or for any nuclear facility) is governed by national legislation and requires safety regulator approval. The safety factors taken into account include a potential site's hydrological, geological, meteorological, seismic and demographic characteristics. The objects are minimising the human and environmental exposure to any release of radioactivity and ensuring that safety-related structures and systems are able to withstand the strongest foreseeable natural or human-induced event, e.g. an earthquake. For these reasons nuclear power stations are, to the extent possible, generally sited away from large population centres. Reevaluation of a site may occur as understanding or methods to assess possible natural or man-made hazards improve.

C____________

The basic design philosophy of nuclear facilities is one of defence in depth, that is, providing several levels of protection against the release of radioactive substances. The first level of defence is the prevention of failures. Thus nuclear designs strive to ensure reliable, stable and easily manageable operation. The use of high-quality technology with allowance for considerable safety margins in the strength and capacity of safety-critical components are vital elements in achieving this. These factors also work to maximise potential productivity and favour safety.

The second level of defence, the detection and control of failures, is to ensure that any deviation from normal operation is quickly detectable and, where possible, is corrected automatically by process control and protection systems, without interfering with normal operation. In case such systems fail due to some abnormal operational occurrence, engineered safety systems (see below) are built in to automatically place the reactor into a safe condition and to contain the radioactive materials.

These systems are designed to withstand the so-called design basis accidents, a set of abnormal occurrences and potential accidents that have been foreseen and provided for in the design. The control of these design basis accidents is the third level of defence.

The design characteristics summarised above represent the first, second and third level of protection in depth against a nuclear accident. The fourth and fifth levels consist respectively in the control of severe accidents with an aim to limit consequences and prevent an external release of radioactivity (if necessary, at the sacrifice of the future operability of the plant), and the mitigation of radiological consequences if in fact a serious release occurs through off-site emergency planning (see Chapter 6 for additional information on accident response).

D______________________

In a nuclear power plant, systems are put in place to ensure that (1) radioactive material is at all times contained, that (2) the fission process can at all times be shut down almost instantaneously if any abnormality persists so as to terminate the generation of all but residual heat, and that (3) residual heat is removed after shutdown in order to protect the integrity of the barriers against a radioactive release. Taking these concerns in order, multiple barriers are provided to prevent the release of radioactivity. The primary containment barriers against a release.

Taking these concerns in order, multiple barriers are provided to prevent the release of radioactivity. The primary containment barriers against a release of radioactivity are the fuel matrix and its hermetic container – the fuel cladding. Next is the robust reactor pressure boundary within which the coolant circulates during normal operation, particularly the pressure vessel that contains the reactor core itself. Normally, the ultimate barrier is the containment building, typically a large reinforced concrete structure designed both to retain the products of an unconfined radioactive release and to protect the structures that constitute the pressure boundary from external hazards such as missiles, fires or explosions (see Figure 5.2). In the Three Mile Island accident in 1979, one of two very serious accidents to have occurred in commercial nuclear power stations, the reactor pressure vessel and containment building successfully prevented any injury to the public, though serious core damage had occurred releasing both intense heat and radioactivity.

The fission process can be shut down by means of neutron-absorbing control rods. These rods can be inserted in a controlled fashion to shut down a reactor slowly or rapidly inserted to almost instantly stop the fission reaction in what is known as a scram. In addition, a secondary means of shutdown is always provided, e.g. by the injection of neutron-absorbing liquids to ensure long-term reactor shutdown.

Heat is normally removed from a reactor by the ordinary operation of the coolant, e.g. for a LWR that means creating steam to drive the electricity-producing turbine generators. Should this fail, separate engineered systems are in place to assure that residual heat (heat generated in the reactor after shutdown) is removed. The power for these and other needed systems is, if necessary, provided by onsite emergency backup generators, typically diesel-fuelled.

The continuous availability and reliable operation of the engineered systems are key elements of defence in depth, and their operation is regularly tested. Design of these systems must ensure that the failure of any single safety component would not cause loss of function (single failure criterion).

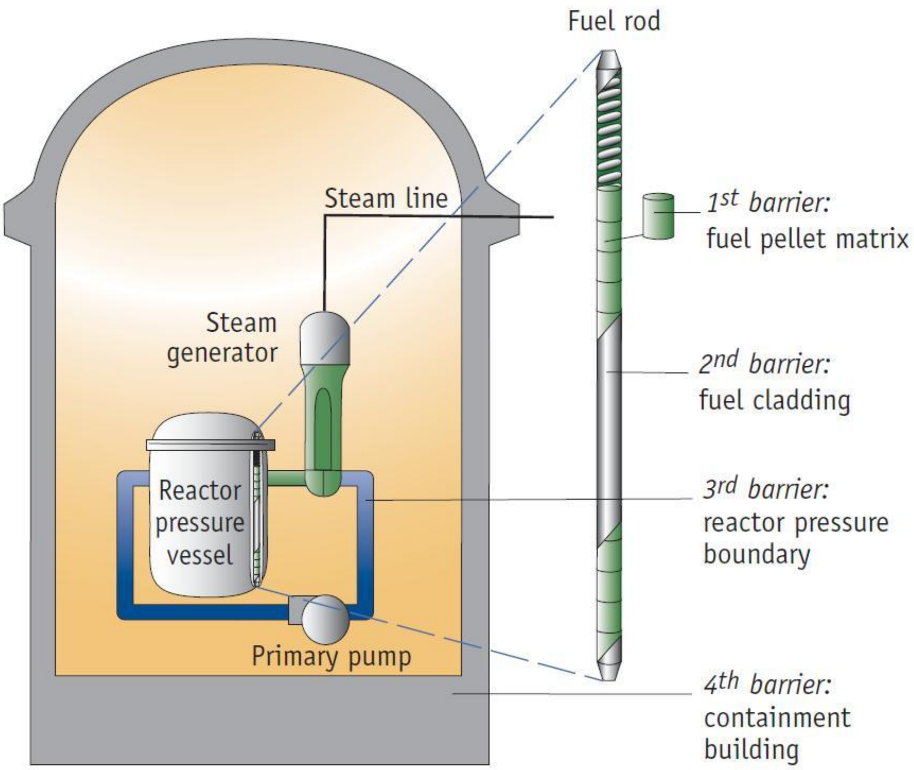


Figure 5.2: Typical barriers confining radioactive materials

Moreover, the safety systems are designed by applying the principles of redundancy, i.e. providing additional backups or greater strength than is needed based on already pessimistic assumptions; diversity, i.e. the avoidance of common cause failure by the provision of several pathways to operation; and the physical separation of safety systems from plant process systems.

Underlying all this is conservatism in all assumptions about risks of failure, the practice of basing design safety on a "what if?" approach and the close analysis of previous component and materials performance.

E__________________________

High-quality equipment is a prerequisite for reliable operation. A special set of codes and standards has been developed for the equipment and components used in any nuclear facility. These demand rigorous testing to confirm that quality standards are met, and their criteria ensure that only well-proven and established technologies are employed.

F__________________________

Commissioning is an important stage in the completion of a nuclear power plant. The reactor power is gradually increased to specified levels and the as-built operating characteristics of the process and safety systems are determined, documented and checked against pre-defined success criteria. A large number of specific tests are conducted to verify the functioning of components and systems and the overall behavior of the plant; weaknesses are corrected, and the tests repeated until satisfactorily completed.

G_____________________

The safety of any nuclear installation must be assessed through a systematic analysis of a defined set of potential failures and their interaction with safety barriers, known as the deterministic safety approach. In the deterministic approach, conservative assumptions are used to demonstrate that the response of the plant and its safety systems to a set of design basis accidents, e.g. a loss of coolant, is within the prescribed regulatory limits and requirements. This approach does not account for the probability of their occurrence and it assumes that all designed safety systems will be available to perform their designed safety function.

It has been common practice since the 1980s to complement the deterministic analysis using a type of analysis called probabilistic safety assessments (PSA). In a PSA, all types of circumstances, including equipment failures and human errors that can lead to an accident, are analysed. The combinations of events and failures that can potentially lead to severe accidents are also identified and their probability of occurrence estimated. The results of these studies are used for a variety of purposes, such as prioritising plant safety improvements, training operators and setting inspection priorities.

H________________

Experience has shown that safe operation depends on adherence to certain principles, including:

● laying the prime responsibility for safety on the operator, with management principles giving the necessary priority to safety;

● a strong organisation ensuring among other things an adequate number and deployment of qualified and experienced personnel;

● establishing conservative limits and conditions that define the safe boundaries for operation;

● approved procedures for all operations including tests, maintenance and non-standard operations that include self-checking and independent verification processes;

● extensive quality-assurance programmes for all operations, inspections, testing and maintenance;

● training programmes for all activities having a direct impact on nuclear safety;

● necessary engineering and technical support throughout the lifetime of the installation;

● timely reporting of all incidents to the appropriate regulatory body;

● the establishment of programmes for collecting and analysing operational experience, and for sharing it with international bodies, regulatory authorities and other operating organisations, and for its incorporation in training programmes;

● the preparation before start-up of emergency procedures and plans, and thereafter their regular rehearsal, so as to harmonise the responses of the various organisations that would be involved in mitigating the consequences of any accident;

● careful consideration of human factors engineering principles in the design and layout of the control room, alarm and indicating systems.

I______________

Experience has shown that a weak "safety culture" is in many cases a root cause of declining safety performance. Despite all the systems-based safeguards, it is the people involved who are the ultimate guarantors of the safety of any nuclear plant. The existence of a good safety culture, which strongly influences the attitudes and states of mind of all the individuals whose actions can impact on safety, is a key nuclear safety principle. The attributes of a good safety culture include a strong sense of responsibility, self-discipline and respect for regulatory requirements on the part of individuals, but management style is also an essential component. Safety culture is not inherent and as it is linked to national habits and attitudes, it cannot be acquired in a short period of time or "installed" like a piece of hardware. It must be transmitted continuously and unmistakably from the top, and permeate the whole of the operating and regulatory organisations.

J_______________________

The responsibility for nuclear safety is foremost a national one with each country responsible for the safety of the nuclear power plants that it has permitted to be constructed and operated within its borders. The prime responsibility for safety is most often assigned to plant operators who are the license-holders. However, international co-operation including organisations such as the OECD Nuclear Energy Agency (NEA) and the International Atomic Energy Agency (IAEA) has always made a fundamental contribution to the development of relevant concepts and the spreading of good practice.

An important principle reflected in the Nuclear Safety Convention is the effective separation between the regulatory organisation and other groups involved in promoting or using nuclear energy, so that the safety authority and its decision-making process are protected from undue external pressure.

K________________________

A great deal of information and many lessons have been gathered from over 10 000 reactor- years of operating experience worldwide. These lessons are routinely shared through such means as databases and reports by international organisations, journals and conferences. A significant result has been a steady improvement in the operating safety performance of nuclear plants, particularly in recent years. For example, the number of unplanned automatic scrams has been decreasing over the past decade, indicating a widespread improvement in plant operation.

The overall good safety record of commercial nuclear power plants is marred by two severe accidents – those at Three Mile Island (TMI) in the United States in 1979 and at Chernobyl in Ukraine resulted in serious damage to the reactor core but the reactor pressure vessel and containment building prevented all but trace amounts of radioactive gases from being released and caused no effect on the population. It was subsequently rated 5 on the INES scale. The Chernobyl accident was on any reckoning a disaster and the only event ever rated above 5 (at 7). At Chernobyl, there was a meltdown of the nuclear fuel that combined with a steam explosion, and the lack of a complete containment building resulted in large amounts of solid and gaseous radioactive materials being widely distributed over Europe.

These two accidents provided important lessons. The TMI accident emphasised the need for greater attention to the human factors, including improved operator qualification and training and better emergency procedures and public communication. The Chernobyl accident, as well as publicising weaknesses in the RBMK reactor design (not present in OECD countries), led to the recognition of the importance of safety culture.

It showed that a weak safety culture not only among operators, but also stemming from weak management and distracting external influences, could lead to operational behaviour breaching every element of defence in depth.

L_____________________

Over the next few decades new reactor designs may be introduced to compete with other sources of electricity. These advanced designs will be faced with the challenge of cutting generating costs while maintaining or improving safety levels. Various concepts of the next generation of nuclear power reactors have been proposed and are being studied. Some safety-related features can be characterised as follows:

- explicit consideration of severe accidents as a part of the design basis;

● effective elimination of some severe accident sequences by use of inherent safety features;

● significant reduction or elimination of large radioactive release even should a severe accident occur;

● improved operability and maintainability by extensive use of digital technology;

● reduction in system complexity and potential for human error.

All of these, if successfully implemented, could result in the reduction of on-site and off-site protective measures, such as evacuation plans for the public and would represent improvements over the current safety posture.

Nuclear Energy Today
Nuclear Energy Agency
Organization for Economic co-operation and development

COMPREHENSION

Activity 3. Find passages from the text where the following ideas have been mentioned:

- Escape of harmful radioactive substances.
- Examples to prove Importance of safety culture
- Verification
- Design basic accidents
- Key nuclear safety principle
- human factors engineering principles

Activity 4. Answer the following Wh-questions on aspects of Nuclear Safety

1. What does nuclear safety depend on?
2. What is regarded as the primary purpose of all nuclear safety measures?
3. How many factors are taken into consideration to achieve nuclear safety?
4. Why is commissioning regarded as an essential stage in the completion of power plant?
5. What are the main responsibilities of NEA and IAEA in terms of nuclear safety?
6. How can the safety level of a nuclear power plant be assessed?
7. What prevents release of radioactivity?
8. What are the safety-related features of next generation nuclear power reactors?

Activity 5. Write down your own definition of Nuclear Safety that you have come up with after reading the text

LANGUAGE PRACTICE

Activity 6. Match the words with their definitions

1. prerequisite	A) evaluation of safety risks
2. robust design	B) to promote the growth and development of
3. fuel cladding	C) to moderate (a quality or condition) in force or intensity; alleviate
4. scram	D) to take back or away; remove
5. foster	E) a structure or system designed to prevent the accidental release of radioactive materials from a reactor
6. maintenance	F) protection system designed
7. emergency	G) an emergency shutdown of a nuclear reactor
8. withdraw	H) established or decided beyond dispute or doubt
9. mitigate	I) the work of keeping something in proper condition; upkeep
10.inherent features	J) the act or practice of positioning successive mutually supporting lines of defence in a given area
11.commission (v)	K) production of fuel
12.defence in depth	L) extra reserve or substitute.
13.adherence	M) a serious situation or occurrence that happens unexpectedly and demands immediate action
14.additional backups	N) to put (a ship) into active service
15.nuclear facility	O) something that is required in advance
16.safety assessment	P) pevere overheating of a nuclear reactor core, resulting in melting of the core and escape of radiation

17.containment	Q) faithful attachment; devotion
18.engineered protection	R) vigorous design
19.deterministic	S) something created to serve a nuclear function
20. meltdown	T) existing as an essential constituent or characteristic

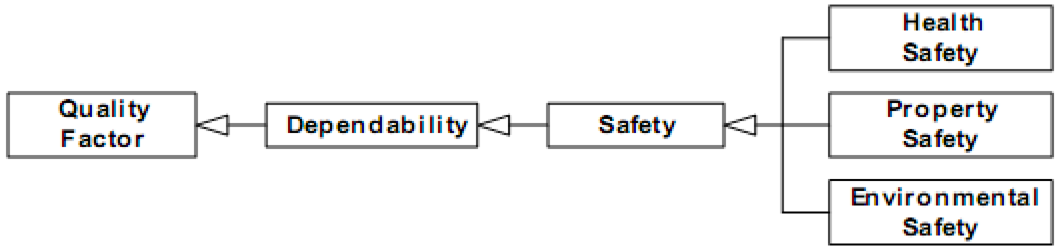
Activity 7. Match two parts of the phrases

1. prevent	A)failures
2. foster	B) safeguards
3. safety	C) backup generators
4. withdraw	D) in depth
5. prevention of	E) assessment
6. adherence to	F) an external release of radioactivity
7. inherent	G) consequences of accidents
8. systems-based	I) the safety culture
9. prerequisite for	J) nuclear fuel
10. onsite emergency	K) a license
11. defence	L) principles
12. prevent	M)accidents from occurring
13. integrity of	N) the barriers
14. meltdown of	O) safety features
15. mitigate	P) reliable operation

Activity 8. Fill in the gapped sentences with the expressions from Activity 7.

1. The idea behind__________ is to manage risk with diverse defensive strategies, so that if one layer of defense turns out to be inadequate, another layer of defense will hopefully prevent a full breach.
2. Tokyo Electric Power Company, operator of the damaged Fukushima Daiichi nuclear power plant, revealed Thursday that nuclear fuel at one of the reactors is in a state of "_______"
3. Number of vehicles on the road in Germany can help to prevent accidents and________
4. A film integrity evaluation method is needed for barrier characterization. The method should be able not only to test the____________ but also to find low-density defects so called ‘‘killer defects’’.
5. Good leadership skills can be developed through practice and ________of emotional intelligence
6. ___________is an interdisciplinary approach that focuses on the scientific understanding and measurement of chemical hazards as well as chemical exposures, and ultimately the risks associated with them.
7. The following steps can help your organization reduce injury rates and ___________
8. Despite all the_____________, it is the people involved who are the ultimate guarantors of the safety of any nuclear plant.

Activity 9. Describe the following flow chart on Nuclear Safety concept while using the words and word combinations from Activity 6 and 7



SPEAKING AND LISTENING

Activity 10. Speculate on the following question: Why do countries come up with decision to obtain nuclear weapons?

Divide into two teams. Your task will be to have your say on obtaining nuclear weapons and persuade the leader of your country either to get them or refuse to obtain them. Team A is striving for the country's nuclear weapons possession whereas Team B is against it.

Activity 11. Previewing vocabulary. Explain the meaning of the following words. Guess what kind of context can be for them to be used

- deter
- overthrow
- be reckoned with
- consolidate political control
- domestic political power
- drive towards the decision

Activity 12. Watch the video where Joseph Cirincione, Center for American Progress, explain the reasons why most of the countries want to possess nuclear weapons.

- According to him, what are the three main reasons?
- What do you think about American and Russian reasoning for obtaining NW? Do they differ from other countries'?

Activity 13. Divide into 2 teams. Think about the script for a short film for nuclear safety specialists to create a safe atmosphere at the nuclear power plant.

As an example you can use a short video on the safety sketches site:

http://www.napofilm.net/en/napos-films/napoepisode?filmid=napo-017-working-together

Present your script using tips on how to use visual aids in EFFECTIVE PRESENTATION section

EFFECTIVE PRESENTATION

Designing Visual Aids

Effective visuals help your audience understand and remember the key points of your presentation. Overhead projectors and slides, blackboards, handouts, and computer programs like PowerPoint can greatly enhance your message if they are used effectively. The following tips will help you design effective visual aids.

Make each visual stand on its own

Each visual needs to be clear and understandable on its own. To help you accomplish this, consider using the following tips:

- limit each slide to only one topic, and give it a relevant title;
- state sources where appropriate – for statistics, figures, pictures, etc.;
- number headings to clearly illustrate where you are in your presentation;
- know your audience: avoid abbreviations and jargon unfamiliar to them;
- use meaningful graphics when they reinforce your written message;
- highlight key information on charts, tables, and graphs to help focus your audience's attention (i.e., use colour, circle the information, or use a pointer);
- make points concise yet meaningful – avoid being cryptic.

Achieve balanced and consistent layouts

Balance and consistency are important when creating a presentation package. While your visuals should be able to stand alone, they also need to fit together into a coherent whole. The following tips should help:

- keep type sizes and fonts consistent on all visuals in a presentation;
- format headings consistently (e.g., use bold text and increased font size);
- use no more than two fonts per slide (one for headings and one for main text) or choose different sizes of the same font for headings and main text;
- spread the information out so that it fills the screen;
- choose contrasting colours (e.g., dark background with light lettering);
- use colour consistently but avoid overuse – two to four colours per slide;
- be aware of the connotations behind colours (e.g., red on a financial statement comes with the negative connotation of having a cash deficit);
- use parallel grammar for points (e.g., begin each point with the same part of speech)

Make visuals easy to read

Visuals are only effective if your audience can physically see them. Here are some tips:

- use 24 - 28 point font for main text and 32 - 40 point font for headings;

- if writing by hand on overhead slides, make your letters at least 1/2” (1.0 cm) high;
- avoid distracting, unnecessary graphics and excessively complex backgrounds;
- use clear, standard fonts such as Times New Roman, Arial, or Helvetica;
- consider using boldface lettering to make text thicker;
- avoid putting much text in italics or all upper-case letters – this slows down reading;
- ensure diagrams are not too intricate to be visible from the back of the room;
- limit each point to one line whenever possible to limit reading time.

Include only your main points

Effective visuals should aid your audience, not you! They are not your lecture notes. The following tips will help you design concise, content-rich visuals:

- write only main points on your visuals, not the details that support them – avoid giving the audience your presentation to read;
- put the key words you repeat throughout your presentation on your visuals (repetition is acceptable in presentations, since it helps audience retention)
- make your points discrete: do not simply break up paragraphs;
- assume your audience will copy down everything you present on a visual – keep information clear, simple, and minimal.

USE VISUAL AIDS TO

- focus the audience's attention
- reinforce the key components of your verbal message
- stimulate and maintain interest
- illustrate complex concepts that are difficult to visualize
- aid the audience's comprehension
- increase retention

DO NOT USE VISUAL AIDS TO

- impress your audience with overlydetailed text, charts, or animations – avoid information overload
- limit interaction with your audience
- present simple ideas that are easily stated verbally
- serve as your cue cards

ESSENTIAL VOCABULARY

1. Nuclear safety
2. Nuclear facility
3. engineered protection
4. basic design philosophy
5. defence in depth
6. accidental escape of harmful radioactive substances
7. Nuclear energy installation
8. prevent accidents from occurring
9. mitigate consequences of accidents
10. siting of installation
11. robust and proven design
12. comprehensive testing prior to operation
13. probability of plant failures
14. safety assessment
15. to foster the safety culture
16. independent regulatory authority
17. to withdraw a license
18. site for a nuclear power plant
19. national legislation
20. withstand natural or human-induced event
21. Reevaluation of a site
22. prevention of failures
23. to favour safety
24. detection and control of failures
25. engineered safety systems
26. design basis accident
27. severe accident
28. prevent an external release of radioactivity
29. residual heat
30. integrity of the barriers

31. fuel cladding
32. reactor pressure boundary (pressure vessel)
33. containment building
34. neutron-absorbing control rods
35. scram
36. onsite emergency backup generators
37. principles of redundancy
38. additional backups
39. prerequisite for reliable operation
40. commissioning of nuclear power plant
41. potential failures
42. deterministic safety approach
43. designed safety functions
44. probabilistic safety assessments
45. human error
46. adherence to principles
47. qualified and experienced personnel
48. maintenance
49. quality-assurance programmes
50. appropriate regulatory body
51. regular rehearsal
52. human factors engineering principles
53. safety performance
54. systems-based safeguards
55. responsibility for nuclear safety
56. license-holder
57. Nuclear Safety Convention
58. INES scale - International Nuclear Events Scale
59. meltdown of nuclear fuel
60. emergency procedures
61. design bases
62. inherent safety features
63. on-site and off-site protective measures

UNIT 10

NUCLEAR SECURITY

All countries should properly handle the relationship between nuclear security and the peaceful use of nuclear energy. – Chinese President Hu Jintao

WARM-UP

Put the countries from the box into the following categories:

China, France, Russia, United Kingdom, United States,
India, Pakistan, North Korea,
Belgium, Germany, Netherlands, Italy, Turkey, Japan,
Spain, Cuba, Mexico, Saudi Arabia, Iraq

1. NPT nuclear-weapon states
2. Other states with nuclear weapons
3. Other states believed to have nuclear weapons
4. Countries that do not possess nuclear weapons

PRE-READING

Activity 1. Scan the text and match the headings with the parts of the text. One heading is extra .

1. Potential impact of nuclear security incidents
2. Importance of the human factor and management leadership in nuclear security
3. Nuclear security regime
4. Role of international community in security culture maintenance
5. Background
6. Relationship between security culture and safety culture
7. Protection of sensitive information and facilities

Activity 2. Some key terms are defined within the reading text. Scan the text to find the definition of the following words and write them in the space provided:

Nuclear security culture____

Human factor____

Nuclear security regime____

Activity 3. Read the text and do the tasks below

NUCLEAR SECURITY CULTURE

In response to a resolution adopted by the IAEA General Conference in September 2002, the IAEA followed an integrated approach to protection against nuclear terrorism. This approach coordinates IAEA activities concerned with the physical protection of nuclear material and nuclear installations, nuclear material accountancy, detection of and response to trafficking in nuclear and other radioactive material, the security of radioactive sources, security in the transport of nuclear and other radioactive material, emergency response and emergency preparedness in Member States and at the IAEA, and promotion of adherence by States to relevant international instruments. The IAEA also helps to identify threats and vulnerabilities related to the security of nuclear and other radioactive material. However, it is the responsibility of States to provide for the physical protection of nuclear and other radioactive material and the associated facilities, to ensure the security of such material in transport, and to combat illicit trafficking and the inadvertent movement of radioactive material. One of the goals of the IAEA nuclear security programme is to provide guidance and assistance to help Member States establish a strong nuclear security culture. This will facilitate and optimize human aspects in their national nuclear security programmes.

An effective nuclear security culture can result in a significant increase in the effectiveness of the security of radioactive material and associated facilities and transport. An enhanced nuclear security culture will provide greater assurance that the entire nuclear security system will accomplish its functions of preventing, detecting, delaying and responding to, theft, sabotage, unauthorized access, illegal transfer or other malicious acts involving radioactive material and the associated facilities and transport. Nuclear security culture is referenced and briefly described in a number of relevant legal instruments and documents. This guide explains the basic concepts and elements of nuclear security culture. It also provides recommendations that will assist States in planning and implementing a programme to improve nuclear security culture with special reference to enhancing this culture in organizations. Particular emphasis has been placed on such areas as regulation, government institutions and general public awareness. The IAEA will develop additional guidance based on the experience with the application of this guidance. The preparation of this publication in the IAEA Nuclear Security Series has involved extensive consultations with Member States, including an open-ended technical meeting in Vienna in March 2006. The IAEA officers responsible for this publication were A.V. Barcena (deceased), B. Weiss and A. Stadalnikas of the Office of Nuclear Security, Department of Nuclear Safety and Security.

A_________________

At the June 2000 meeting of the Working Group of the Informal Open-

Ended Expert Meeting to Discuss Whether there is a Need to Revise the Convention on the Physical Protection of Nuclear Material (CPPNM), it was suggested that “an analysis of INFCIRC/225/Rev.4 (Corrected) could be performed in which the Physical Protection fundamentals and Requirements embedded in its text could be extracted.” The Physical Protection Objectives and Fundamental Principles, which this meeting subsequently endorsed, included ‘Security Culture’ (Fundamental Principle F) as follows: “Security Culture: All organizations involved in implementing physical protection should give due priority to the security culture; to its development and maintenance necessary to ensure its effective implementation in the entire organization.” This was further endorsed by the IAEA Board of Governors at its September 2001 meeting and welcomed by the General Conference, which in a resolution stated that due priority should be given to security culture. These objectives and fundamental principles were subsequently incorporated into the Amendment to the CPPNM agreed by consensus by its States Parties in July 2005. In March 2005, the IAEA international conference on Nuclear Security: Global Directions for the Future, held in London, recognized that the risk of successful malicious attacks remains high and stated: “The fundamental principles of nuclear security include embedding a nuclear security culture throughout the organizations involved. By the coherent implementation of a nuclear security culture, staff remain vigilant of the need to maintain a high level of security.” In addition, it should be noted that the IAEA Code of Conduct on the Safety and Security of Radioactive Sources contains the following basic principle: “Every State should, in order to protect individuals, society and the environment, take the appropriate measures to ensure … the promotion of safety culture and of security culture with respect to radioactive sources.” [Basic Principle 7(b)] These texts provide the basis for developing a clear concept of what nuclear security culture is and how it should be developed and maintained.

Nuclear security culture is defined as: The assembly of characteristics, attitudes and behaviour of individuals, organizations and institutions which serves as a means to support and enhance nuclear security1. An appropriate nuclear security culture aims to ensure that the implementation of nuclear security measures receives the attention warranted by their significance.

B______________

Threats to nuclear security involve criminals or terrorists acquiring and using for malicious purposes: (a) nuclear weapons; (b) nuclear material to build improvised nuclear explosive devices; and/or (c) radioactive material to cause harm to individuals or the environment, including the construction of radiological dispersal devices (RDDs) and radiological exposure devices (REDs). Such threats could also include: (d) the dispersal of radioactive material through the sabotage of facilities in which radioactive material can be found or of such material in transport. These could be outsider/insider threats. The political and economic consequences, and the impact upon human health and the environment, of the malicious use of radioactive material could be devastating, particularly in the case of a nuclear explosive device, and could be unpredictably disruptive in the case of malicious acts resulting in the dispersal of radioactive material. Nuclear security culture plays an important role in ensuring that individuals, organizations and institutions remain vigilant and that sustained measures are taken to prevent and combat the threat of sabotage or using radioactive material2 for malicious acts.

C_______________

A nuclear security regime includes a range of elements and activities, including: legislation and regulation; intelligence gathering; assessment of the threat to radioactive material and associated locations and facilities; administrative systems; various technical hardware systems; response capabilities and mitigation activities. No single government or industry organization or subsection of such an organization can address these elements in isolation. An effective nuclear security culture is dependent on proper planning, training, awareness, operation and maintenance, as well as on people who plan, operate and maintain nuclear security systems. Even a well designed system can be degraded if the procedures necessary to operate and maintain it are poor, or if the operators fail to follow procedures. Ultimately, therefore, the entire nuclear security regime stands or falls because of the people involved and their leaders, and it is the human factor, including management leadership, that must be addressed in any effort to enhance the existing nuclear security culture.

D_________________

A human factor is generally a contributor to all nuclear security related incidents as well as malfunctions related to activities involving radioactive material. In this regard, leadership and management can be vital components. They include deliberate malicious acts, unintentional personnel errors as well as ergonomic issues related to the design and layout of software and hardware, inadequate organizational procedures and processes and management failures. Individual understanding of and commitment to roles and responsibilities, commitment to continuous improvement, and management commitment are of great importance to nuclear security.

E_____________________

While both nuclear safety and nuclear security consider the risk of inadvertent human error, nuclear security places additional emphasis on deliberate acts that are intended to cause harm. Because security deals with deliberate acts, security culture requires different attitudes and behaviour, such as confidentiality of information and efforts to deter malicious acts, as compared with safety culture. Safety culture is defined as “that assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, protection and safety issues receive the attention warranted by their significance".

In a similar manner, nuclear security culture refers to the personal dedication and accountability and understanding of all individuals engaged in any activity which has a bearing on the security of nuclear activities. Therefore, the principal shared objective of security culture and safety culture is to limit the risk resulting from radioactive material and associated facilities. This objective is largely based on common principles, e.g. a questioning attitude, rigorous and prudent approaches, and effective communication and open, two way communication. Many diverse organizations are concerned with nuclear security. These include, in particular, individuals, organizations and institutions engaged in protecting radioactive material and their associated locations, facilities and transport; some of these bodies may have little technical knowledge about nuclear or other radioactive material. This lends greater weight to the need for effective structural, communication, information and exchange systems, and the integration of the functions of these diverse organizations into a unified nuclear security culture.

Competent authorities for safety and security may be located in the same, or different, organizations and may have different forms of supervisory or regulatory power. In each case, many individuals are part of both the security and safety cultures. For safety culture, all individuals are prevailed upon to share information openly because of this area's overriding concern for transparency and dialogue. In the same way, security culture requires that individuals respond immediately to confirmed or perceived threats and incidents, and restrict communication to authorized persons with a need to know. Safety and security cultures coexist and need to reinforce each other because they share the common objective of limiting risk. There will be occasions where there are differences between safety and security requirements. Therefore, an organization in charge of nuclear matters has to foster an approach that integrates safety and security in a mutually supporting manner.

Nuclear security culture
Implementing guide
International Atomic Energy Agency, Vienna, 2008

COMPREHENSION

Activity 4. Decide if the statements are true or false

1) An integrated approach to protection against nuclear terrorism was followed by the IAEA pursuant to the resolution taken in September 2002.
2) States are liable to help in threats and vulnerabilities identification attributed to nuclear and other radioactive material.
3) One of the IAEA objectives within nuclear security program is to induce Third Parties to optimize human aspects in thirds countries national nuclear security

programs.

4) Malicious acts involving radioactive material and the associated facilities are reckoned to be prevented, detected or responded to in case of enhanced nuclear security culture.
5) Such areas as regulation, government institutions and general public awareness are brought into focus in the abovementioned guide.
6) IN September 2001 General Conference: Global Directions for the Future, held in London, acknowledged that the risk of successful malicious attacks remains high and announced that the fundamental principles of nuclear security include embedding a nuclear security culture throughout the organizations involved.
7) The basis for developing a clear concept of what nuclear security culture is and how it should be developed and maintained is provided in the resolution adopted in 2002.
8) Menace to nuclear security involves culprits or perpetrators of acts of terrorism acquiring and using for malicious purposes nuclear weapons, nuclear or radioactive materials.
9) A nuclear security regime stands or falls due to the individuals involved and leaders, and it is the human factor that must be resorted to in any effort to enhance the existing nuclear security culture.
10) The main objective of both security culture and safety culture is to enhance the risk resulting from radioactive material and associated facilities.

Activity 5. Answer the WH- questions:

1. What does the abbreviation IAEA stand for?
2. What is coordinated by means of the integrated approach to protection against nuclear terrorism followed the IAEA?
3. Why is an enhanced nuclear security culture needed?
4. Is an additional guidance planned to be developed by the IAEA and what is the reason therefore?
5. What was suggested during the meeting of the Working Group of the Informal Open-Ended Expert Meeting?
6. What is the nuclear security culture defined as?
7. What is ensured by an appropriate nuclear security culture aims?
8. What are the probable threats to the nuclear security?
9. What does an effective nuclear security culture depend on?
10. Why are the human factor and management leadership important in nuclear security?
11. What do nuclear safety and nuclear security have in common?

LANGUAGE PRACTICE

Activity 6. Fill in the table where possible

verb	***noun***	***adjective***	***adverb***	***Antonym to the verb***
	response			
emerge				
		applicable		
		legal		
	priority			
			correctly	
endorse				
	exposure			
			vigilantly	
		dispersal		
	intelligence			
				complicate
		disruptive		

Activity 7. Match nouns with the appropriate adjectives

1. strong	a) instruments
2. associated	b) acts
3. Inadvertent	c) meeting
4. illicit	d) facilities
5. Unauthorized	e) effect
6. due	f) threat
7. devastating	g) installations
8. illegal	h) measures
9. insider	i) Nuclear security culture
10. relevant	j) trafficking
11. appropriate	k) priority
12. Malicious	l) access
13. nuclear	m) transfer
14. international	n) instruments
15. technical	o) movement

Activity 8. Find prepositions to the following phrases from the text

In response….	be concerned…	Be in charge….	Reference….
Result…	be endorsed…	Commitment…	Be responsible….

LISTENING AND SPEAKING

Activity 9. Speculate on the following idea:

How difficult would it be for a terrorist to obtain a nuclear weapon?

Activity 10. In what context do you think the phrase " to give a high level presidential attention" can be used in the video

Activity 11. Previewing vocabulary for listening. Match the words with their definitions

1.	Obtain (v)	a) capability in terms of personnel and material that affect the capacity to build s
2.	From scratch	b) to work slowly
3.	Industrial capability	c) a large store or supply accumulated for future use
4.	Beyond the means	d) from the very beginning.
5.	Durable	e) multiply useful materials
6.	stockpile	f) impossible to do
7.	To move at a snails pace	g) very long lasting
8.	Increase resources	h) to gain possession of; acquire; get

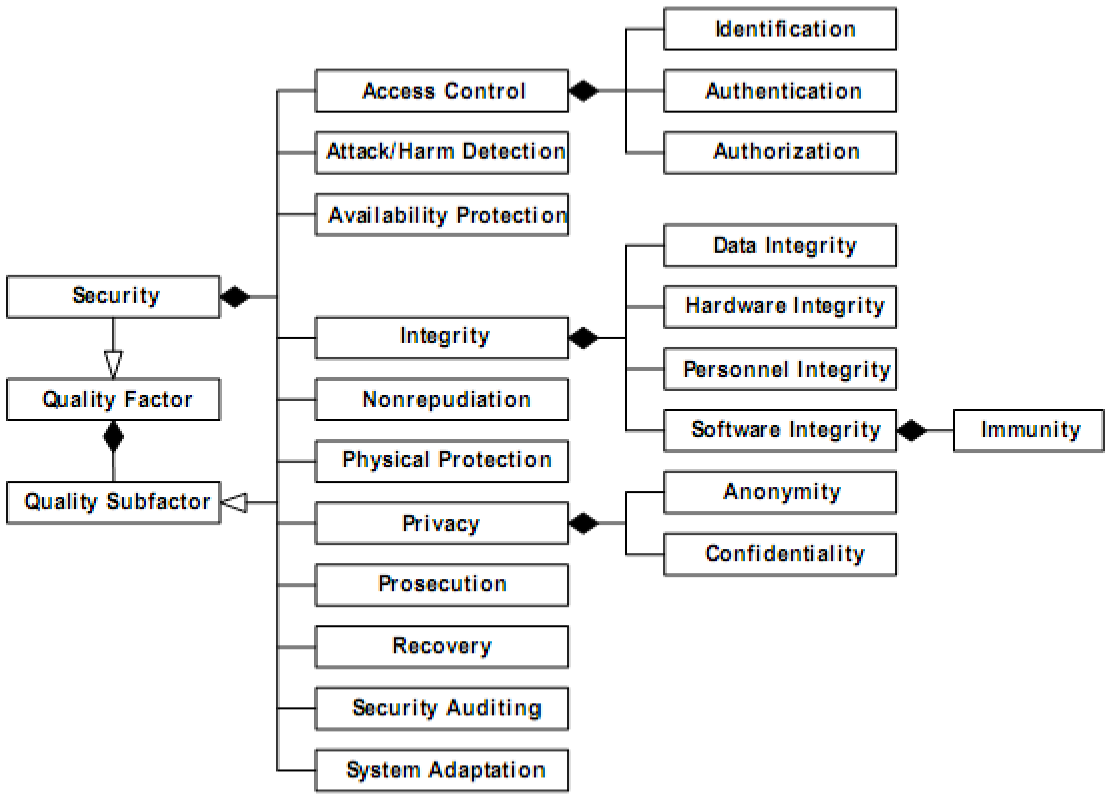
Activity 12. Watch the video "The Choices Program"

Watson Institute of International Studies Brown University www. choices.edu and answer the following questions:

1. Why is it possible for a terrorist group to build a nuclear weapon from scratch?
2. What resources does building nuclear weapons require?

3. How has the fact that making a nuclear bomb from scratch is possible if under certain circumstances been proved?
4. What is being done to prevent a nuclear theft?
5. What must be done to make nuclear program work more effectively?
6. What should be done to completely eliminate the possibility of making nuclear bombs by terrorists?

Activity 13. Discuss with the partner what aspects of security presented on the diagram below Joseph Cirincione, head, American Progress Center has mentioned?



Activity 14. Divide into 2 teams and come up with the ideas how to express your concern about the security measures at the nuclear power plant in your city and call for enhanced nuclear security the local government\ director of a nuclear power plant. Use EFFECTIVE PRESENTATIO N Techniques from the section below

EFFECTIVE PRESENTATION

The introduction is a very important - perhaps the most important - part of your presentation. This is the first impression that your audience have of you. You should concentrate on getting your introduction right. You should use the introduction to:

- ✓ *welcome your audience*
- ✓ *introduce your subject*
- ✓ *outline the structure of your presentation*
- ✓ *give instructions about questions*

The following table shows examples of language for each of these functions. You may need to modify the language as appropriate.

Function	**Possible language**
Welcoming your audience	• Good morning, ladies and gentlemen • Good morning, gentlemen • Good afternoon, ladies and gentleman • Good afternoon, everybody
2 Introducing your subject	• I am going to talk today about... • The purpose of my presentation is to introduce our new range of...
3 Outlining your structure	• To start with I'll describe the progress made this year. Then I'll mention some of the problems we've encountered and how we overcame them. After that I'll consider the possibilities for further growth next year. Finally, I'll summarize my presentation (before concluding with some recommendations).
4 Giving instructions about questions	• Do feel free to interrupt me if you have any questions. • I'll try to answer all of your questions after the presentation. • I plan to keep some time for questions after the presentation.

ESSENTIAL VOCABULARY

1. In response to
2. To be concerned with
3. Nuclear installations
4. Emergency response
5. Emergency preparedness
6. International instruments
7. Identify threats
8. Reference to
9. Responsible for
10. Vulnerabilities
11. Ensure security
12. Inadvertent movement
13. Facilitate
14. Optimize
15. Result in
16. Associated facilities
17. Strong nuclear security culture
18. Enhanced nuclear security culture
19. Accomplish functions
20. Respond to
21. Unauthorized access
22. Illegal transfer
23. Illicit trafficking
24. Malicious act
25. Relevant instruments
26. Implement a program
27. Improve nuclear security culture
28. Place an emphasis on
29. Develop additional guidance
30. Open-ended
31. Technical meeting
32. Revise convention
33. Due priority
34. To be endorsed by
35. Embed NSC
36. Take appropriate measures
37. Warrant (v)
38. Build a device
39. Improvised nuclear explosive devices
40. Cause harm
41. RDD
42. RED
43. Sabotage of facilities
44. Outsider\insider threats
45. Devastating effect
46. Disruptive
47. Vigilant
48. Assessment of threat
49. Associated locations
50. Be dependent on
51. Awareness
52. Follow procedures
53. Nuclear security related incidents
54. Malfunctions
55. Vital components
56. Deliberate acts
57. Personnel error
58. Ergonomic issues
59. Commitment to
60. Deter malicious acts
61. Unified nuclear security culture
62. Share information openly
63. Limit the risk
64. Be in charge of nuclear matters
65. Foster approach
66. Shared objective
67. Rigorous approach

UNIT 11.

SAFEGUARDS

The history of liberty has largely been the history of the observance of procedural safeguards
Felix Frankfurter

WARM-UP

Critical thinking. Speculate on the statement by former IAEA Director-General Dr Mohamed El Baradei.
"… we are only as effective as we are allowed to be."

What implications does this statement have?

Discuss with your partners the reasons why current international safeguards are not so “safe”.

PRE-READING

Activity 1. Guess what the following abbreviations stand for:

- IAEA
- NPT
- NW
- NM
- UNO

Activity 2. Previewing vocabulary. Explain the meaning of the following phrases. What context can they be encountered in?

- Sophisticated attacks
- Illegal shipments
- Nuclear smuggling
- International security environment
- Comprehensive safeguards

Activity 3. Read the text and do the tasks below.

PREVENTING NUCLEAR PROLIFERATION

International Safeguards

The International Atomic Energy Agency (IAEA) has the traditional responsibility for detecting the diversion of nuclear materials (NM) from civilian to military purposes in states that have joined the Treaty on the Nonproliferation of Nuclear Weapons (NPT) and pledged no to acquire nuclear weapons (NW). To fulfill this mission IAEA has created an organization of international safeguards inspectors who utilize dozens of specialized procedures and technologies to maintain confidence that member states are not diverting NM. The IAEA now has the additional task of determining the completeness of states` declarations of their nuclear activities and developing confidence that no undeclared nuclear activities exist within member states.

To achieve this new objective, the IAEA is encouraging member states to sign in Additional Protocol to their safeguards agreements, permitting the IAEA greater access to inspections and information regarding nuclear activities in that state. Although most states with significant nuclear activities have not yet ratified protocol nor brought it into force on their territories. Fundamental to the new approach to IAEA safeguards are information acquisition, evaluation, and analysis along with inspections. The new approach is designed to provide an evaluation of the nuclear program of a state as a whole and not just each of its declared nuclear facilities.

The goal of comprehensive international safeguards agreements is to detect the diversion of significant quantities of nuclear material from peaceful purposes within certain tame periods. A significant quantity of nuclear material is defined by the IAEA as approximate amount of nuclear material from which a nuclear explosive device could be manufactured. For highly enriched uranium, this quantity is 25 kilograms; for plutonium it is 8 kilograms.

The IAEA has established safeguards criteria for each type of nuclear facility under safeguards. These criteria are used as templates for defining safeguards activities at specific facilities within country, including the scope, the normal frequency, and the extent of the verification activities needed to achieve the inspection goals. For comprehensive safeguards agreements, the technical objectives of safeguards are the timely detection of the diversion of nuclear material from peaceful uses and the deterrence of such diversion by the risk of early detection. These objectives also include the detection of undeclared production or separation of direct-use material at reactors, reprocessing facilities, facilities with hot cells, and enrichment installations.

Nuclear materials accounting records of all nuclear materials on inventory changes are maintained by operators for each facility under safeguards. This information should be identical to that which exists in each state`s "domestic" system of accounting and control. This inventory information and safeguards-relevant design information are transmitted through the state authorities to the IAEA. The state declarations on the nuclear materials present at facilities and facility operations provide a baseline for the IAEA`s verification activities. For comprehensive safeguards agreements with additional protocols, the overall objective is to provide credible assurance of both the nondiversion of nuclear material from declared activities and of the absence of undeclared nuclear material and activities in the state as a whole.

The concept of voluntary implementation of the Additional Protocol among

IAEA member states includes the idea of incentives. Some states, after having implemented the Additional Protocol on all their nuclear facilities for several years, can eventually have a decreased safeguards burden in terms of IAEA presence with in their facilities. This is because they will have reached a status where “integrated’ safeguards, including facility inspections, complimentary access, and information analysis, are now believed to be in effect. This allows some inspections activities to be reduced within country without a loss of confidence that its safeguards agreement is being fulfilled.

PART II

Detecting Undeclared Nuclear Activities

Every state that developed nuclear weapons has done so in secret, at least initially. Consistent with this trend there now exists a clear record of states that have accepted legal obligations not to develop nuclear weapons but nevertheless pursued nuclear weapons development in violation of those obligations. This list includes Iraq, Libya, North Korea, and most likely Iran. The secret development of nuclear weapons by additional states, especially by those that have formally rejected these weapons, can cause tension, regional instability, and distrust that increase proliferation incentives for neighboring or rival states. Because this negative pattern may continue, it is important to the security of the United States and the international community that tools are available for the detection and analysis of secret or undeclared nuclear activities. Such tools will also be important for monitoring the nuclear weapons programs of Israel, India, and Pakistan, states that have not signed the NPT.

Confirming the Elimination of Nuclear Weapon Program

Another important aspect of nuclear security in the 21st century will, hopefully, be the challenge of confirming that nations that have started nuclear weapons programs and then pledged to abandon them have actually done so. It is clear that the set of factors that lead a nation to acquire a nuclear arsenal can change, prompting the nation to decide that nuclear weapons are no longer in its interest. Several specific cases have demonstrated this situation since the early 1990s, and IAEA has taken an active role in them.

Preventing Nuclear Terrorism

The possibility that terrorists might acquire and use nuclear weapons is an urgent challenge to global security. Today, a terrorist nuclear attack is thought to be more likely than an exchange of nuclear weapons with another state. Terrorist networks have proven that they are capable of sophisticated attacks involving dozen of heavily armed assailants. There is a very strong consensus among terrorists experts that anti-Western Islamic extremism will persist for many decades, and many such experts predict that it will become more widespread and more violent and will concentrate on attacks with weapons of mass destruction, including nuclear weapons.

Another great challenge for nuclear security in the 21st century will be improving the integration or coupling of technical and administrative systems that are responsible for securing nuclear materials at their authorized locations, prosecuting individuals or groups who seek such materials, and detecting their illegal shipment. The interrelationship of these problems is clear, but the global infrastructure to prevent them still operates like three or more disconnected organizations. For example, those responsible for physical security at a nuclear facility should know in detail whether or not nuclear smuggling rings or terrorists have been active in their location, but this information has traditionally resides with law enforcement agencies. Another example is that customs or border officials operating nuclear materials detection systems could do so much more effectively if they knew what type of nuclear materials were missing from what location or how they were being transported. The laws that require nuclear facility managers to report missing materials within a certain time or to a certain degree of detail vary widely across the world. These are many other shortcomings need attention in the years ahead.

Summary

The management of nuclear security in the post-Cold War era is a complex and evolving challenge for the international community. Fortunately, there has so far been no catastrophic use of nuclear weapon or materials or the confirmed theft of a nuclear weapon or large quantity of weapon-usable nuclear materials. However, there have been many cases of states violating their legal nonproliferation obligations and of individuals conducting illegal trade in nuclear materials, technology, and knowledge. Even more troubling is that many nations have nuclear materials security and export control system that require significant improvement to effectively prevent illegal loss or trafficking of nuclear materials, technology, and knowledge. The IAEA has limited resources and political authority to address these shortcomings. Meanwhile, large stocks of excess Cold War fissile materials have yet to be rendered nonweapons-usable, even as civilian stocks of plutonium continue to grow.

While there are encouraging international developments such as U.N. Security Council Resolution 1540, the IAEA's Additional Protocol, and the proliferation Security Initiative, these efforts are in their early stages, and their full implementation is uncertain. In addition, the international security environment remains such that additional states will probably seek nuclear weapons or the capability to acquire them rapidly for reasons of security and influence. In short, there is clearly a need for continuous, vigorous efforts to improve the technological and human capital that managing nuclear security will require. It is our hope that Nuclear Safeguards, Security, and Nonproliferation: Achieving Security with Technology and Policy will contribute to this effort by helping to inform a new generation of nuclear security students and practitioners.

James E.Doyle

Nuclear safeguards, security, and nonproliferation

Achieving Security with Technology and Policy

Elsvier Inc, 2008

READING COMPREHENSION

Activity 4. On reading about international safeguards, can you add to your answer to the question posed above on the reasons why current international safeguards are not so "safe". Check your guesses on the abbreviation from Activity 1.

Activity 5. Scan the text and find the information that is reflected in the following figures:

1. 25
2. 8
3. 21
4. 1540
5. 1990

Activity 6. Decide whether the following statements are true or false.

1. The IAEA now has the additional task of determining the completeness of states` declarations of their nuclear activities and developing confidence that no undeclared nuclear activities exist within member states.
2. The goal of Additional Protocol is to detect the diversion of significant quantities of nuclear material from peaceful purposes within certain tame periods.
3. The IAEA has established unified safeguards criteria for all types of nuclear facility under safeguards.
4. The concept of voluntary implementation of the Additional Protocol among IAEA member states includes the idea of integration.
5. Today, a terrorist nuclear attack is thought to be more likely than an exchange of nuclear weapons with another state.

LANGUAGE PRACTICE

Activity 7. Find the verbs that can collocate with the following nouns or noun groups. More than one variant can be possible.

Example: noun phrase "nuclear arsenal" collocates with the verb "acquire". The answer is to *acquire nuclear arsenal***.**

1. diversion of nuclear materials
2. mission
3. nuclear weapons programs
4. greater access

5. protocol
6. credible assurance
7. nuclear weapons
8. urgent challenge to global security
9. obligations
10. nuclear materials

Activity 8. Make up sentences of your own using the verb+noun expressions from Activity 7 to show how they function in speech.

Activity 9. Look at the picture. Tell what it shows using all the words from the table below

Diversion of nuclear materials	Nuclear states	Nuclear weapon	Arsenal
Nuclear umbrella	Non-possessor states	Nuclear stockpile	Nuclear program

LISTENING AND SPEAKING

Activity 10. Previewing vocabulary. Look through the list of words from the video on the brief History of the Atomic Age. Work with a partner from your group. Partner A explains the words from the 1st column. Partner B works with the 2d column. Use dictionary if needed

- Fellow-physicist
- Numerical superior
- Armament race
- Renunciation
- Stringent international control
- Endowment
- Raise the stake (v +n)
- Policy of extermination
- Civilian population
- Preventive measures
- Mushroom (v)
- Nuclear test site
- High tension
- Put the world on edge

Activity 11. Divide into 2 teams. Watch the video A Brief History of the Atomic Age Part 1 http://www.youtube.com/watch?v=wAZlO1CqMnU&feature=related

Team A fill in the first column from the table. Team B fill in the last column.

Dates	*Events*	*Famous people involved*
	Scientists wrote a letter where they described the possibility of nuclear bomb existence	
	Nuclear weapon program started	
	First committee on proliferation	
	First use of an atomic bomb	
	The proposal to the UN to eliminate nuclear weapon	
	Committee on Atomic Energy was formed	
	Complete plan on nuclear material control	
	Plan to eliminate nuclear Weapons in US was approved	
	Armament race began	
	First US nuclear tests	
	First USSR nuclear tests	

Now, one member from Team A gets together with a member from Team B. You are to exchange the results of watching by asking questions to each other.

Activity 12. Watch the video one more time. Make notes if necessary and then dwell on the milestones of Atomic Age history using EFFECTIVE PRESENTATION techniques below.

EFFECTIVE PRESENTATION

Communicating your content effectively

- ✓ The body is the main part of your presentation. This is where you explain your topic and where all our information is presented. The organization of the body is critical because the audience needs to be able to follow what you are saying and/or doing.
- ✓ A demonstration is the easiest to organize because you can simply go through the steps in order. The audience must know what is being done, how it's being done, and why it's being done.
- ✓ Illustrated talks or speeches are usually organized by arranging major points and discussing them. You should limit these major points to three to five. If you have more than five, the audience can get lost or confused. If you have fewer than three, you probably don't have enough information or your topic is too simple or narrow.
- ✓ Arrange your points in a logical order and then give information to support each point. Examples of ways to organize points are to number them (1, 2, 3....); put them in a time frame (past, present, future); use narration (tell a story from beginning to end); or present them as a problem-effect-solution (state a problem, describe its effect, then suggest ways to solve the problem).
- ✓ No matter how you organize the body of your presentation, you must have clear transitions from point to point or step to step. There are many ways you can help the audience identify these transitions.

Count on your fingers, step 1, step 2, etc. Use transition words such as then, next, finally, or one reason, another reason, or first, second, third. Pauses are a good way to emphasize transitions. Movement can also indicate a transition. Try changing your position in front of the audience or witching posters. All information you present in the body of your presentation must be accurate and understandable. You need to offer enough information to cover your topic thoroughly while eliminating any unnecessary information.

USEFUL LANGUAGE

Introduce each point with an expression from the list below.
The first/key thing to say about ___________ is...
The main point to make about ___________ is...
What you really need to know about___________ is ...
Now let's look at...
Let's turn to/move on to ...
Another interesting thing to say about___________ is ...
Finally, I'd like to say a few words about...

ESSENTIAL VOCABULARY

1. acquire a nuclear arsenal
2. baseline
3. civilian/peaceful or military purposes
4. completeness of states' declarations
5. comprehensive safeguards agreements
6. defining safeguards activities
7. detect the diversion of nuclear materials
8. deterrence of diversion
9. develop nuclear weapon
10. direct-use material
11. diversion of nuclear materials
12. elimination of nuclear weapons programs
13. export control system
14. fulfill the mission
15. illegal shipment
16. incentive
17. information acquisition
18. international safeguards
19. international safeguards agreements
20. international safeguards inspectors
21. international security environment
22. inventory
23. law enforcement agencies
24. monitoring the nuclear weapons programs
25. nondiversion
26. nonweapons-usable
27. nuclear explosive device
28. nuclear smuggling
29. nuclear smuggling rings
30. permit greater access
31. ratify protocol
32. sign in Additional Protocol
33. undeclared nuclear activities
34. provide credible assurance
35. rival states
36. safeguards criteria
37. seek nuclear weapons
38. significant quantities of nuclear materials
39. sophisticated attacks
40. tension / regional instability / distrust
41. theft of a nuclear weapon
42. bring into force
43. trafficking

44. undeclared nuclear activities
45. undeclared production
46. urgent challenge to global security
47. violation of obligations
48. voluntary implementation
49. weapon-usable nuclear material
50. weapons of mass destruction (WMD)

UNIT 12

NUCLEAR TECHNOLOGIES.

NUCLEAR MEDICINE

And Lord, we are especially thankful for nuclear power, the cleanest, safest energy source there is. Except for solar, which is just a pipe dream.

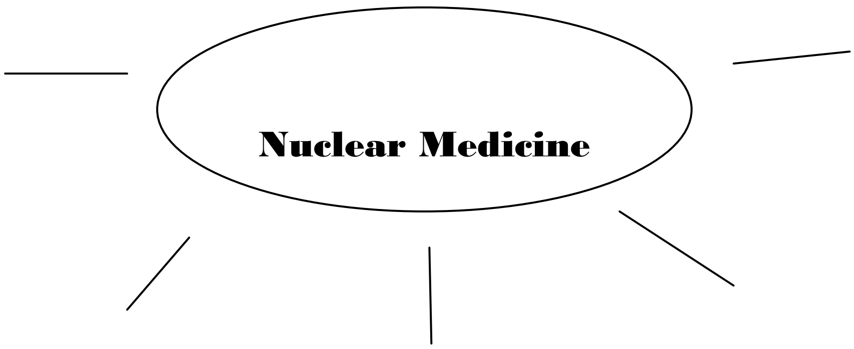
Dan Castellaneta

WARM-UP

✓ ***Look at the picture above. Discuss what it is depicted and what nuclear issues are related to the picture.***

✓ ***Divide into two groups. In your groups discuss what spheres of life are influenced by nuclear technologies nowadays and what nuclear technologies you can name.***

✓ ***One of the most important fields of nuclear technology application is nuclear medicine. Brainstorm on the information and words you know about it.***



PRE-READING

Activity 1. Speculate on the following questions:

- What do you know about such radioactive elements as technetium-99 (Tc-99m) and molybdenum-99 (Mo-99)? What productions are they used in?
- Why can technetium-99 (Tc-99m) and molybdenum-99 (Mo-99) be of some interest to terrorist?

Activity 2. Previewing vocabulary. Think how the following words can be related to nuclear medicine context

- Nuclear terrorism;
- highly enriched uranium;
- low-enriched uranium;
- nuclear reactor;
- molybdenum-99;
- technetium-99m;

- medical isotopes

Activity 3. Read the text, find out whether your predictions were correct and do the tasks below.

NUCLEAR MEDICINE'S DOUBLE HAZARD

Imperiled Treatment and the Risk of Terrorism

The most important isotope used in nuclear medicine today, metastable technetium-99 (Tc-99m), the daughter product of molybdenum-99 (Mo-99), is primarily supplied on a worldwide commercial basis by just four producers, all of which rely on a small number of nuclear research reactors that use highly enriched uranium (HEU) targets to produce Tc-99m. This state of affairs is potentially hazardous for two critical reasons. First, medical patients are now dependent on too few nuclear reactors, with too great a risk that shutdowns could result in cancellations of lifesaving treatments. Second, HEU target material can be used to fabricate a nuclear bomb. The technology to produce Mo-99 using low-enriched uranium (LEU) targets is proven, available, and has been used routinely by two smaller producers for a number of years (moreover, other non-HEU production technologies also exist). However, political determination and financial support to convert the major producers' isotope production to LEU has been lacking. There are currently no commercial incentives for lead producers to convert from HEU use. Though the market for radioisotopes is expanding rapidly, with new production capacities needed to ensure radioisotope supply, high up-front costs, low profit margins, and difficult licensing processes mean that the establishment of new facilities is extremely difficult without government intervention. Meanwhile, policies related to HEU conversion and medical isotope production have wavered over the years. A new political commitment to support increased Mo-99 production without the use of HEU is essential. Otherwise the general public will continue to face a double hazard: insufficient future supplies for medical treatment along with the possibility of nuclear terrorism.

This article first reviews the main uses of Tc-99m before turning to a history of its production, including past efforts to ensure a reliable medical isotope supply. Next, it examines broader policies enacted to reduce the use of HEU and these policies' influence on medical isotope production, with a particular focus on U.S. legislation related to HEU exports and on programs aimed at converting Mo-99 production from HEU to LEU and producing Mo-99 without the use of nuclear targets. It concludes with a review of current policy and activities in this area and suggests measures to ensure supplies and reduce future risks. The risks inherent in the current system of isotope production became particularly apparent in 2007, after revelations of operating license violations and security breaches at isotope production reactors in Canada and South Africa. The prolonged November December 2007 shutdown of Canada's National Research Universal (NRU) reactor* triggered when it was discovered that two emergency pumps were not attached to emergency power supplies, as required by its operating license*dramatically reduced Tc-99m supply throughout North America. Production resumed only after the Canadian parliament countermanded Canada's nuclear safety commission. In addition to questions about nuclear safety in Canada, this countermand focused concerns on the world's overwhelming reliance on a single Canadian reactor for medical isotopes. It also sent a dangerous message to other countries regarding regulation of their own nuclear facilities. Grant Malkoske, vice president of the Canadian company MDS Nordion, the world's largest producer of Tc-99m, reportedly had warned officials before the crisis erupted that in the event of a prolonged shutdown of the Canadian reactor, ''we could see a global supply shortage of 30 percent.'' Another recent incident, the November 8, 2007 break-in at South Africa's Pelindaba facility, which also produces Mo-99 and has large supplies of HEU stored on-site, raised new questions about the security of that facility and the potential vulnerability of the weapon-grade material stored there. Armed attackers approached the facility from two sides; one group, able to defeat the facility's security system, entered the main emergency control room. Even though the attackers were apparently after computers, not uranium, the incident is disturbing when one considers that Pelindaba houses enough HEU to create multiple bombs. Therefore, any security breach should raise concerns and this was the second reported breach at the site in the past couple of years. Further, as the supplier of some 15 percent of the world's Tc-99m, the secure and reliable operation of the SAFARI- I reactor at Pelindaba is critical to the world supply of this radioisotope.

Nuclear Medicine's Workhorse

Radioisotopes have important medical, scientific, and industrial purposes. The most widely used of these isotopes is Mo-99, which is used to produce Tc-99m, which is employed in some 30 million medical diagnostic procedures worldwide every year 80 percent of all nuclear medical procedures. There are more than a hundred different such procedures in nuclear medicine to determine the severity of heart disease, the spread of cancer, and the diagnosis of brain disorders about 70 percent of which rely on Mo-99. Tc-99m is recovered from generators at clinics and laboratories, which receive them from pharmaceutical suppliers. Because the half-life of Mo-99 is just sixty-six hours, the useful lifespan of a Tc-99m generator is about one week. Thus a constant and reliable supply of Mo-99 is critical for nuclear medicine. At present, most production of Mo-99 takes place in nuclear reactors where a ''target'' (i.e., a special fuel element) made of enriched uranium is irradiated in a high flux area of the reactor. The target is then dissolved in either nitric acid or alkaline solutions for one to three hours, after which the Mo-99 can be recovered and purified by a variety of processes. The Mo-99 is then sent to the manufacturer of Tc-99m generators, who must then quickly forward equipment to hospitals and other users.

Nuclear Isotope Production Facilities and Risks

The amount of HEU used for medical isotope production was relatively small twenty-five years ago (in both absolute terms and as a percentage of all HEU in civilian use), when the Reduced Enrichment for Research and Test Reactors (RERTR) program to reduce use of HEU in the civilian sphere was initiated. Today, however, the amount of HEU used in targets for Mo-99 production is an increasing proportion of all HEU uses and is projected by some to increase to half of the HEU in civilian use by 2020 (assuming present trends and no conversion to LEU by the major Mo-99 producers).

Mo-99 is currently produced in at least nineteen countries, with the largest four producers located in the European Union, Canada, and South Africa. More than 90 percent of the world's supply of medical isotopes comes from MDS Nordion (Canada, using the NRU reactor), Covidien (formerly Mallinckrodt, using reactors in Belgium and the Netherlands), Institut National des Radio elements (IRE, using multiple le European reactors), and NTP Radioisotopes (Pty) Ltd. (South Africa, using the SAFARI reactor). Only Australia and Argentina rely on LEU targets for isotope production; while Argentina's production is small, Australia intends to become a large-scale producer within the next few years (see Figure 2). In addition, countries like India and China engage in small-scale production through neutron activation (without the use of uranium targets), mostly for local users (see Figure 3). However, all of the world's largest producers currently rely upon HEU targets in their isotope production programs (the enrichment level of targets varies from 36?45 percent in South Africa, to about 93 percent in Canada).

Although the quantity of HEU employed to produce Mo-99 was initially quite small, in 2007 the amount of uranium-235 (U-235) used by the world's four main Mo-99 producers totaled about 50 kilograms (kg), a quantity sufficient to produce two nuclear bombs. This contrasts with about 750 kg presently used worldwide to refuel research reactors, although this latter number has been decreasing each year, while there have been no decreases in the amount of HEU used for target production. If current estimates by U.S. Department of Energy (DOE) officials with the RERTR program prove to be correct and new fuel types allowing conversion of many research reactors are available in 2014, then soon afterward half of the HEU in use in reactors worldwide may be in fission targets for radioisotope production (if reactors are converted or shut down while HEU-based isotope production continues at full capacity). Moreover, many of the reactors currently used to produce isotopes are reaching the end of their service lives. Thus, key decisions on investments in new reactor and processing capacities will have to be made within the next few years.

HEU targets used in Mo-99 production pose particular risks that make conversion of this production to LEU particularly important. Because of the relatively short time targets remain in a reactor (low burn up), the U-235 content of a spent 93 percent U-235 target is still above 90 percent HEU. Furthermore, because the target waste is in liquid form (acid dissolution) and in solid form as hydrated uranium oxide solid (alkaline digestion), it can be relatively easily converted into HEU metal (the material used in the production of a gun-type nuclear explosive device) via well-known chemical processes. And finally, short irradiation time means that targets are not as ‘‘self-protecting’’ (highly radioactive) as spent reactor fuel.

Currently, security standards in most nations are based on worker safety regulations that consider the health effects of longtime exposure to nuclear materials in the workplace. For a worker in a Mo-99 generator production facility, the large volumes of target waste are sufficiently radioactive to be dangerous (and are therefore considered ‘‘self-protecting’’). However, for a terrorist wishing to obtain enough HEU for a single weapon, the target waste can be contact-handled (and converted into uranium metal) without shielding after a cooling period of just three years, exposing the perpetrator to doses hazardous to long-term health but not sufficient to disable the person handling the material, a recent Argonne National Laboratory study indicates. In this scenario, only relatively small amounts of target waste (some 80 grams) need be handled at any one time; once each such batch is converted to metal (using the well-known PUREX process, which chemistry graduate students should be capable of handling), it can be stored while the next batch is processed.

The study notes:

Considering that 5?8 million millirem (mrem) are required to cause immediate disorientation and coma in seconds or minutes, the received dose for removal of large quantities of this material would not be consequential to a dedicated terrorist. Converting this material to a weapon would not require elaborate shielding and could be performed in a garage with minimal dose to the processors. This dose rate is much lower than that produced by spent research reactor fuel. The Argonne report cites a dose rate of about 40 mrem per hour per gram of initial uranium fora spent HEU material test reactor fuel element burned to 60 percent (measured at 1 meter per gram of uranium), and concludes that because of its greater U-235 fraction (approximately 92 percent) and its lower dose rate, spent HEU target material is a far greater security and safeguards concern than spent research reactor fuel. Thanks to the success of the various Global Threat Reduction Initiative programs, the amount of HEU used for isotope production has become a relatively greater proportion of the HEU in use in the civilian sphere.16 Unfortunately, there are already hundreds of kilograms of target waste containing only slightly irradiated HEU, resulting in a greater quantity of HEU stored at these processing facilities than is held at the majority of research reactors.

Storage and processing of HEU target waste poses safety as well as security problems. For example, because Canada’s facility for this liquid waste is full, its operators have conducted criticality studies to ensure that storage could be reconfigured to accommodate additional material or that some waste could be removed and immobilized in concrete to reduce overfill. Of course, the immobilized material will eventually have to be removed from the concrete in order to downblend it for long-term storage not a simple process. Waste storage space is problematic for other radioisotope producers, too. For example, like Nordion, the Mallinckrodt medical company (now Covidien) had intended to send its target waste to the Dounreay reprocessing facility in Scotland, before Dounreay was suddenly shut down in 1998. European plans still call for recycling of HEU target waste for production of new targets; while such plans will cut down on HEU in storage, it is not clear that this recycling will occur on-site. If not, the HEU will have to be taken to a facility for recycling and transported back to the reactor*adding yet another site of concern, along with increasing transportation (nuclear materials are generally considered to be most vulnerable during transport, where fewer security measures are usually available than at fixed facilities).

Reducing the overall volume of target waste in storage has tangible security benefits, but complete elimination of the HEU is a much more reliable option. As far as the author is aware, the only security upgrades at Mo-99 production reactors since September 11, 2001, have been at the BR-2 reactor in Belgium, and even there security may be strong for a civilian site but not when compared to military facilities. Security at isotope irradiation and production facilities around the globe was not designed to prevent terrorist attacks or the theft of materials for the construction of an improvised nuclear device (IND). Indeed, few countries have updated their security requirements sufficiently since 9/11.17

On the whole, requirements should be updated to include consideration of new threats, and the concept of ''self-protection'' of nuclear materials should be revised to reflect the amount of radiation required to incapatate would-be thieves (such a change is under way in the United States). These new requirements should include more nuanced recommendations than those in the current International Atomic Energy Agency (IAEA) guidelines on the physical protection of nuclear material and nuclear facilities. Security requirements for nuclear power plants are insufficient for Mo-99 production, given that the material at the latter facilities is weapon-grade; requirements for protecting most spent research reactor fuel are similarly not enough, given the much lower levels of radioactivity found in irradiated targets. In short, sites handling HEU targets for Mo-99 production should have the same level of protection as materials at military facilities, because they too can be used to create a nuclear weapon.

Cristina Hansell
http://cns.miis.edu/npr/pdfs/152_hansell_nuclear_medicine.pdf

COMPREHENSION

Activity 4. Scan the text and find out what the following figures and numbers and abbreviation are related to:

- 2007
- 30
- 90
- 5-8

- 1998
- HEU
- DOE
- IND

Activity 5. These are topic sentences that summarize the idea of the article. Find 1-2 supporting ideas to each of them from the text

1. This article examines the production of metastable technetium-99 (Tc-99m), the world's most important radiopharmaceutical, focusing on reliability of supply and risks of nuclear terrorism.
2. Only four producers manufactured about 95 percent of the world's Tc-99m; a closure of any of them could cause worldwide shortfalls.
3. Moreover, all four employ highly enriched uranium in their production process, in a form relatively easy to convert into the metal needed for a nuclear bomb.
4. The technology to employ low-enriched uranium (LEU)*not usable in weapons*to produceTc-99m is proven, available, and has been used by smaller producers.
5. However, politicaldetermination and sufficient funding are needed to convert the major producers' isotope production to LEU and encourage new LEU-based production. Such efforts are needed to ensure supplies and reduce security risks.

LANGUAGE PRACTICE

Activity 6. Match the nouns with the suitable attributes (adjectives or attributive groups). Find the context for these expressions in the text.

1.Useful	A) product
2.Daughter	B) shielding
3.Critical	C) future
4. Lifesaving	D) concern
5.Insufficient	E) lifespan
6.Inherent	F) risk
7.Security	G) exposure
8.Overwhelming	H) reasons
9.Reliable	I) waste
10.Acid	J) terrorist
11. Gun-type nuclear	K) explosive device
12.Target	L) security benefits
13. Longtime	M) operation

14.Dedicated	N) breaches
15. Elaborate	O) producers
16.Security and safeguards	P) thieves
17. Radioisotope	Q) nuclear device
18.Tangible	R) reliance
19.Improvise	S) dissolution
20.Would-be	T) treatments

Activity 7. Fill in the following table

Verb	***Noun***	***Adjective***	***Antonym to the verb***
		reliable	
dissolve			
	improvisation		
treat			
		risky	
	shield		
			eliminate
explode			
		elaborate	

Activity 8. Fill in the missing words in the text below from the table

1. discovery	2. commercial	3. medical procedures	4. demand	5. bodily organs	6. experiments
7. reliable	8. ensure	9. radioisotope	10. producer	11. supplies	12. technetium

Ensuring Mo-99 Supplies

The United States was the first A____ of Mo-99 and continues to be the world's largestuser of Tc-99m. Concerns over maintaining a sufficient and B____supply of this isotope have been voiced since the late 1960s, soon after the C___of Tc-99m and its applications. As new uses for this D_____continue to be discovered, and its use spreads rapidly throughout the world, the difficulty of ensuring adequate E_____of Tc-99m is likely to increase. The following section reviews the history of Mo-99 generator production and early efforts to F___supplies to U.S. users.

The discovery that Mo-99 could generate Tc-99m was made by accident at Brookhaven National Laboratory in 1958 during G_____involving another isotope. The use of H_____as a medical tracer was first put forward by a Brookhaven scientist, Powell Richards, at the International Electronic and Nuclear Symposium in Rome in June 1960. Richards also promoted its use to the University of Chicago, which developed many I _____using Tc-99m in the 1960s. The half-life of Tc-99m is six hours*long enough for a medical examination, but short enough to avoid radiation damage to J___. Mo-99, on the other hand, has a half-life of sixty-six hours, making it possible to transport over fairly long distances. Mo-99 was initially produced by the Atomic Energy Commission at the Brookhaven and Oak Ridge National Laboratories, but by 1966 the national laboratories could no longer keep up with K___ for Tc-99m generators and withdrew from production and distribution, letting commercial enterprises take over. The first L___ generator was produced by Nuclear Consultants, Inc. of St. Louis (later taken over by Mallinckrodt), and Union Carbide Nuclear Corporation, New York.20 Production also began in Canada: on May 1, 1970 at the NRU reactor, and on May 1, 1971 at the Nuclear Research Experimental (NRX) reactor, both at Atomic Energy of Canada Limited's Chalk River Laboratories in Ontario.21

LISTENING AND SPEAKING

Activity 10. Speculate on the following issues related to nuclear medicine

- ✓ Do you have any ideas what the job of nuclear medicine technologists implies?
- ✓ What are the professional requirements for such a person?

Now, you are going to watch two episodes related to the job of nuclear medicine technologist and check if your guesses were correct.

Activity 9. Previewing the vocabulary. Look through the list of words. Guess their meanings. Use monolingual dictionary if needed.

Video 1.

- Amateur
- Metabolic imaging
- Cardiovascular

- Benign diseases

Video 2.

- By mouth
- With injection
- Track (v)
- Course of treatment
- Exposure to radiation
- Imaging procedure

Activity 10. Watch video 1 and answer the question:

What does the job of nuclear medicine technologists imply?

Watch video 2 and answer the question:

What are the professional requirements for such a person?

Activity 11. Make a small presentation on the profession of nuclear medicine technologists using techniques from EFFECTIVE PRESENTATION section

EFFECTIVE PRESENTATION

Finishing the presentation. Conclusion

Your conclusion should be short and concise. It should summarize or highlight the main points you made or emphasize what the audience should have learned.

- ✓ Do not restate everything you said in the body and never introduce new information at this time. A good conclusion ties together all the parts of your presentation.
- ✓ Try to include some sort of link to your introduction. Avoid false or multiple endings. End with a catchy phrase and leave the audience with a good impression.

- ✓ After your conclusion, you need to state your sources of information. These could include books, magazine articles, or interviews with people. If you've used material from the Internet, don't state entire websites. Just give key search words.
- ✓ Last, you need to ask for questions. Be sure that you repeat each question before you give an answer. Not only does this ensure everyone hears the question, but it gives you the chance to make sure you understood the question. If you get a question you can't answer, simply say you don't know. Never make up an answer or bluff. If possible, provide a resource where the answer could be found. It isn't practical to offer to look it up and get back to the person.
- ✓ When there are no more questions, a simple "thank you" to finish is enough. Don't thank the judge for listening or various people for giving you help. If it's appropriate, you can invite.

USEFUL PHRASES TO CONCLUDE PRESENTATION

In conclusion,... ;To sum up,...
So, remember that……..is all about…….. , __, and .
So, there are three things to remember about__
Does anybody have any questions?

ESSENTIAL VOCABULARY

1. Daughter product
2. HEU target
3. State of affairs
4. Lifesaving treatment
5. Fabricate a nuclear bomb
6. Convert the major production
7. HEU conversion
8. Face a double hazard
9. Ensure supply
10. Nuclear targets
11. Inherent risk
12. Operating license
13. Security breach
14. Trigger (v)
15. Countermand
16. Focused concern
17. Shutdown
18. Break-in
19. Weapon-grade material
20. Armed attackers
21. Raise concern
22. Medical diagnostic procedures
23. Useful lifespan
24. High flux area
25. Civilian use
26. Neutron activation
27. Refuel research reactor
28. Service lives
29. Acid dissolution
30. Longtime exposure
31. Millirem
32. Dedicated terrorist
33. Global Threat Reduction Initiative program
34. Downblend (v)
35. Occur on-site
36. Tangible security benifits
37. As far as the author is aware
38. Would-be thieves
39. Security requirements
40. irradiated targets
41. handle HEU targets

APPENDIX 1.

COURSE PROJECTS

Project 1.

Research Reactor

The Research Reactor (RR) is a facility of Research Nuclear Institute (RNI). RNI is located in a semi-arid environment with shrubs, cacti, hardy desert trees, and grass. Small animals such as rabbits, squirrels, prairie dogs, and coyotes inhabit the area. Birds of all sizes are also present. The climate is a typical high-desert environment with approximately 300 clear days of bright sunshine per year.

The RR is a light-water moderated reactor with highly enriched uranium (HEU)-fueled. Nuclear Materials in Use at the RNI are 70 kg of fissile materials including 40 kg of HEU. The reactor is used for research on advanced reactor components, special fuel assemblies, and production of radionuclides for the medical industry. Other experiments are performed to investigate power reactor fuel when heated to the point of melting. A neutron radiography facility is available as well as irradiation tubes and hot cell facilities.

Under the Russian Law Physical Protecting System includes:

- Fire alarm system
- Access control system
- CCTV

Plans of a terrorist group (5people) to attack RR and to steal nuclear materials for realization.

Project Task Description

There are the following steps :

- characterize facility operations and conditions that influence physical protection.
- define threats to determine what the protections must guard against.
- identify targets, areas, and materials that need to be protected.
- identify the physical protection system to protect against the defined threats and to protect the identified targets.
- design physical protection system for your facility.
- prepare 10-minutes presentation about your PPS.

Team members

1. Nuclear Safety specialist
2. Nuclear Security specialist
3. Safeguard Analysis specialist

Project 2.

Power Reactor

Light Water Reactor (LWR) is a 5th Unit of Nuclear Power Plant (NPP). NPP is located on the coast of the sea in northern country with tundra climate. The country doesn't have a lot of fluctuation between day and night temperatures, but wind gusts and changes in wind direction can quickly change the weather and temperatures. The wind is stronger in winter. The temperature is cold, especially in winter. No trees grow here, plants can't push roots into frozen ground. Only small Arctic animals live here, include: Arctic wolf, Arctic fox, Arctic weasel, Arctic hare.

LWR cooled and moderated using ordinary water taken from the lake situated near the sea. Fuel is 50 tones low enriched (4.4% 235U) uranium dioxide (UO_2) in the core. Water in the reactor serves both as a coolant and a moderator which is an important safety feature. Should coolant circulation fail the neutron moderation effect of the water diminishes, reducing reaction intensity and compensating for loss of cooling, a condition known as negative void coefficient. Reactor fuel rods are fully immersed in water kept at 15 MPa of pressure so that it does not boil at normal (220 to over 300 °C) operating temperatures.

Under the Russian law Physical Protection System includes:

- Fire alarm system
- Access control system
- CCTV

Plans of a terrorist group (4 persons) to attack NPP and to explore the core.

Project Task Description

There are the following steps :

- characterize facility operations and conditions that influence physical protection.
- define threats to determine what the protections must guard against.
- identify targets, areas, and materials that need to be protected.
- identify the physical protection system to protect against the defined threats and to protect the identified targets.
- design physical protection system for your facility.
- prepare 10-minutes presentation about your PPS.

Project 3.

Breeder Reactor

The Breeder Reactor (BR) is a facility of Industrial Nuclear Plant (INP). INP is located in a tropical country characterized by high rainfall, with definitions setting minimum normal annual rainfall between 1750–2000 mm. It is hot, wet and humid there. The temperature in a rain forest rarely gets higher than 93 °F (34 °C) or drops below 68 °F (20 °C); average humidity is between 77 and 88%; rainfall is often more than 100 inches a year. There is usually a brief season of less rain. In monsoonal areas, there is a real dry season. Common characteristics found among mammals and birds (and reptiles and amphibians, too) include adaptations to a life in the trees

BR is a nuclear reactor that generates new fissile material (for example Pu) from natural U and generate less waste. Now facility is not operated, and free of fuel. On territory of INP is situated spent fuel storage with 1300 kg of spent fuel contained Pu^{239}.

Physical Protecting System includes:

- Fire alarm system
- Access control system
- CCTV

Plans of a terrorist group (5 persons) to attack RR and to steal nuclear materials.

Project Task Description

There are the following steps :

- characterize facility operations and conditions that influence physical protection.
- define threats to determine what the protections must guard against.
- identify targets, areas, and materials that need to be protected.
- identify the physical protection system to protect against the defined threats and to protect the identified targets.
- design physical protection system for your facility.
- prepare 10-minutes presentation about your PPS.

Team members

1. Nuclear Safety specialist
2. Nuclear Security specialist
3. Safeguard Analysis specialist

APPENDIX 2.

COURSE PROJECTS

EVALUATION SHEET

Give a score 1-5 for each category: 5=outstanding, 1=poor

Parameters	1	2	3	4	5	6	7	8
1. Relevance of the content to the topic indicated								
2. Clear, appropriate structure of the presentation								
3. Ability to set up clear objective of the presentation								
4. Coherence, cohesion of the content								
5. Ability to answer questions								
6. Appropriate use of visual aids (ability to deal with them in a relevant way)								
7. Audience rapport								
8. Eye contact								

9. Pace of speech (too quick, too slow or just right)								
10. Voice (clear enough? varied in pitch or monotonous)								
11. Appropriate Posture								
12. Appropriate Gestures								
13. Fluency, grammatical and lexical accuracy of language								
Total								

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