Radon - a Dangerous Link in the Decay Series of Uranium

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For the
My Environment, My Health, My Choices project

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Abstract:

The environmental hazard associated with radioactive radon gas is used to motivate students' interest in transmutation and the decay series of uranium. This learning experience will make students aware of the risks of exposure to radon. Students will discover the sequence of transmutations in the decay series of uranium-238 and recognize radon as the only gaseous isotope produced. Correct notation for writing isotopes and predicting the products of alpha and beta emissions, as well as an introduction to natural transmutation, are the chemistry goals of this learning experience.

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Teachers, we would appreciate your feedback. Please complete our brief, online Environmental Health Science Activity Evaluation Survey after you implement these lessons in your classroom.
The survey is available online at: www.surveymonkey.com/s.asp?u=502132677711

Radon Pre/Post Test

NAME ………………………………….

1. Radon enters the home and living space primarily through
   1. faulty heating and air conditioning equipment.
   2. the toxic release from some chemical insulations.
   3. soil and bedrock under foundations or basements.
   4. chemical reactions between household cleaning products.

2. Radon is a threat to the environment and human health because
   1. it is a gas.
   2. each radon atom releases several alpha particles.
   3. the radiation emitted is very penetrating.
   4. it is very chemically active.

3. Which nuclear equation represents beta decay?

   1. $^{27}_{13}Al + ^{4}_{2}He \longrightarrow ^{30}_{15}P + ^{1}_{0}n$

   2. $^{238}_{92}U \longrightarrow ^{234}_{90}Th + ^{4}_{2}He$

   3. $^{14}_{6}C \longrightarrow ^{14}_{7}N + ^{0}_{-1}e$

   4. $^{37}_{18}Ar + ^{0}_{-1}e \longrightarrow ^{37}_{17}Cl$

4. In the equation the symbol X represents

$$^{234}_{90}Th \longrightarrow ^{234}_{91}Pa + X$$

   1. $^{0}_{+1}e$

   2. $^{0}_{-1}e$

   3. $^{1}_{0}n$

   4. $^{1}_{1}H$

5. Given the nuclear reaction:

$$^{60}_{27}Co \longrightarrow {}^{0}_{-1}e + {}^{60}_{28}Ni$$

This reaction is an example of
   1. fission
   2. artificial transmutation
   3. fusion
   4. natural transmutation

6. The most penetrating type of radiation is
   1. alpha
   2. beta
   3. gamma
   4. visible

7. Radon is best described as a(n)
   1. reactive and radioactive element.
   2. reactive and stable element.
   3. unreactive and radioactive element.
   4. unreactive and stable element.

8. Which type of reaction results in one element changing to a different element?
   1. neutralization
   2. polymerization
   3. substitution
   4. transmutation

9. Prolonged exposure to radon gas has the most harmful effect on the human
   1. lungs
   2. brain
   3. stomach
   4. eyes

10. A home with dangerous radon levels can be modified and made safe by
   1. treating the radon and making it non-radioactive.
   2. installing gas barriers and a ventilation system.
   3. changing the home's heating system to a steam system.
   4. replacing the insulation and installing new storm windows.

RADON PRE/POST TEST

TEACHER ANSWER KEY

1. Radon enters the home and living space primarily through
   1. faulty heating and air conditioning equipment.
   2. the toxic release from some chemical insulations.
   3. **soil and bedrock under foundations or basements**.
   4. chemical reactions between household cleaning products.

2. Radon is a greater threat to the environment and human health because
   1. **it is a gas**.
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  1. reactive and radioactive element
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8. Which type of reaction results in one element changing to a different element?
  1. neutralization
  2. polymerization
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  4. **transmutation**

9. Prolonged exposure to radon gas has the most harmful effect on the human
  1. **lungs**
  2. brain
  3. stomach
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10. A home with dangerous radon levels can be modified and made safe by
  1. treating the radon and making it non-radioactive
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  4. replacing the insulation and installing new storm windows

Learning Context

Subject Areas: Chemistry, Physical Science (grades 9-12)

Overall Purpose:

Radon is a topic that fits directly with concepts in the Chemistry core curriculum. Many individuals may be unaware of the scope of the problem and the number of individuals who die of lung cancer every year as a direct result of their exposure to radon. There are some simple, inexpensive steps that anyone can do to determine if radon is a problem in their living space. Giving students knowledge about radon's presence in our environment, its detection in our living spaces and the risks of long-term exposure to it, gives them power. They are old enough to talk to their parents now about the dangers and they will continue to be informed citizens for life.

- This learning experience will focus students' awareness on the extent of the environmental health hazard posed by radioactive radon gas in homes. The common methods to detect and reduce concentrations in a home will be included.
- The types of radiation and radioactive particles that are harmful to living cells are described. The definition of natural transmutation and the sequential nature of a decay series will be discovered by the students.

Learning Objectives: Through these learning activities, students' will

a) describe the extent of the environmental health hazard posed by radioactive radon gas in homes;
b) use GIS technology to determine predicted radon levels in the United States;
c) describe the common methods to detect radon in the home and select an appropriate testing site;
d) list and describe the types of radiation and radioactive particles that are harmful to living cells;
e) use correct notation to describe radioisotopes and radioactive particles;
f) define and recognize natural transmutation reactions;
g) write a nuclear reaction for alpha and beta decay;
h) construct the decay series of uranium-238;
i) recognize radon as the only gaseous radioisotope formed;
j) construct and display the sequence of other natural decay series when given the radioisotopes and modes of decay;
k) identify some of the health problems associated with prolonged radon exposure; and
l) identify factors that increase the risk of health problems from radon gas.

Prerequisite knowledge and skills: Students should already

- be familiar with the electromagnetic spectrum, wavelength and frequency;
- be able to use the atomic number to identify a specific element; and
- have a basic understanding of atomic structure and the nucleus.

Procedure

Classroom Timeline:

This learning experience consists of 9 activities that will require approximately three (3) 45-minute class periods.

The pre-test should be given to the students a day or more before this learning experience begins.

Class 1: Complete activities #1 through #4. Additional time may be needed depending on how much time is allowed for students to explore the GIS information on the EPA website; 15-20 minutes would probably be a minimum for gathering useful GIS information gathering. Students should have access to a computer with internet capabilities.

Class 2: Show the "Transmutation and Decay Series" PowerPoint which develops transmutation vocabulary and rules. Activities 5, 6a, and 6b are then used to explore the decay series for uranium-238 in linear and 2-D graph format during class. Activity 7 provides individual practice outside of class. (Emphasis on radon being a gas is a very important point in this lesson).

Class 3 builds upon the physical and chemical properties of radon discussed in the past two periods. Students first examine some actual radon test kits and construct a flowchart describing their proper use. Then they Use the "Citizen's Guide to Radon" to write a letter responding to a hypothetical radon test result in a relative's home. They will address the increasing risk of health problems at higher concentration levels as part of their letter. The post-test would be administered a day or so after completing the activities.

There are three Appendices with this learning experience:

- Appendix A - student handouts
- Appendix B - information on teaching strategies incorporated in this learning experience
- Appendix C - teacher answer keys

Equipment and Supplies:

Equipment:

Computer access with Internet connection for students
TV or project for class viewing of the PowerPoint

Supplies:

Post-It notes for student use (3 per student)
Copies of *EPA "Citizen's Guide to Radon"* (1 per student)
Markers, assorted
Tape, masking
Periodic Tables with atomic numbers and element names (1 per student)
Letter size envelopes (1 per student)
Radon test kits for students to examine

7-E Overview of Radon Learning Experience

Day	PART OF 7-E MODEL	ACTIVITY	STUDENTS WILL:
Prior to learning experience	ELICIT	PRE-TEST	take Pre-test
Class 1	ELICIT AND ENGAGE	TOPICAL BAROMETER ACTIVITY #1	use sticky notes to assign environmental health risk to radon
	ELICIT AND ENGAGE	K-W-L ACTIVITY #2	listen to article describing radon discovery in Pennsylvania home
	ENGAGE	FOCUSED WRITING ACTIVITY #3	respond to short video clips encouraging testing for radon
	ENGAGE AND EXPLORE	ON-LINE GIS ACTIVITY #4	visit EPA web site to discover extent of problem and look for patterns
Class 2	EXPLAIN	THINK-PAIR-SHARE ACTIVITY #5	write nuclear equation for alpha & beta decay transmutations
	EXPLAIN AND EXPLORE	THINK-PAIR-SHARE FOLLOW-UP ACTIVITY #6a	use their results to construct a linear decay series for U-238
	ELABORATE	THINK-PAIR-SHARE FOLLOW-UP ACTIVITY #6b	convert linear format to 2-D graph to show the pattern
Homework	EXTEND	INDIVIDUAL PRACTICE ACTIVITY #7	practice nuclear equations and make a 2-D graph for U-235
Class 3	EXPLORE AND EXPLAIN	FLOWCHART OF RADON TEST USE ACTIVITY #8	construct a flowchart using directions on the radon test kit and then place it in school
	EVALUATE	AUNT GLADYS LETTER ACTIVITY #9	respond to letter and test results to evaluate and advise possible action
After Learning Experience	EVALUATE	POST-TEST	take Post-test

RADON IN THE ENVIRONMENT

Class 1: BACKGROUND FOR THE TEACHER

Radon gas is a radioactive element that is one of the products of the decay of uranium present in the bedrock of a region. It is found in all parts of the United States. Radon concentration can build up in basements and enclosed areas where the gas can seep in through cracks and openings in foundations and walls. The EPA and other health monitoring groups have identified radon as a serious health hazard with a definite link to lung cancer. (EPA 2)

The alpha particles released when the radioisotope, radon-222, undergoes transmutation can cause damage to cells. The ionizing radiation can break bonds and interfere with the normal replication of DNA on the molecular level within the cell. These altered molecules can then code incorrectly, cause abnormal divisions and be a precursor to cancerous growths. (BEIR 2)

Because it is a gas, radon poses a unique environmental threat. Although it is a *chemically* inert element because of its complete octet of valence electrons, it does release an alpha particle as the decay of uranium proceeds toward a stable isotope of lead. The atoms that result from the decay of radon, called radon progeny, are electrically charged and can attach themselves to tiny dust particles in indoor air. These tiny dust particles can easily be inhaled into the lung and can adhere to the lining of the lung where they will decay and release further alpha radiation. (BEIR 1) The natural process of transmutation will continue inexorably, regardless of conditions or consequences. It is the single step that produces radon gas in the sequence that unleashes the atom to be much more likely to have adverse effects on humans and our environment.

Understanding the scientific facts, as well as the health hazards of exposure of our cells to ionizing radiation, is critical to our making responsible and safe decisions for our long-term health. Radon is fairly inexpensive to remediate from our living spaces and reduce risks; the first and vital step is recognition of the danger.

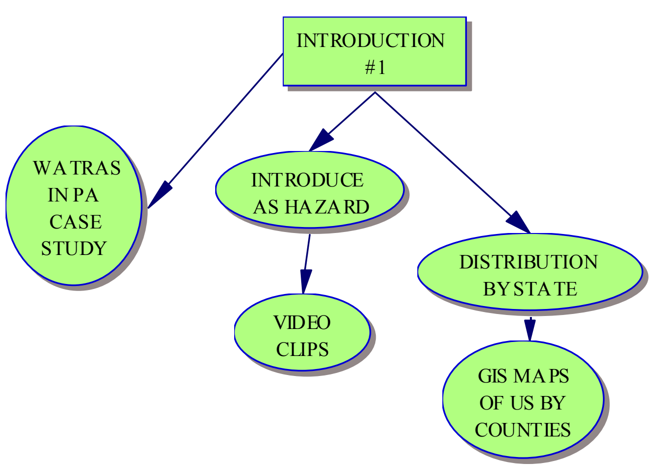

Figure1: Diagram showing introductory materials chosen to engage students in the unit. By K.L., 2006

The introduction to the activity engages the student by presenting an indication of the type and extent of the problem. It is a national concern; no individual or area is exempt from the potential damage.

The case of the nuclear technician in Pennsylvania is a dramatic introduction. The Watras home was so contaminated with radon gas that he triggered the exposure sensors at work when he reported to work. Even the most knowledgeable among us would have no outward physical clues to the presence of incredibly high concentrations of radioactive radon. (Shabecoff 3)

The Surgeon General mounted a full-scale media campaign to alert citizens everywhere to the dangers of radon. The size and scale of the blitz should be an indication of the extent of the danger.

GIS maps are used to inform students of the geographical regions of the country that pose various levels of radon risk. Use of GIS technology allows them to quickly check on the expected levels where they live, where extended family may live or even where they may be considering attending college.

Immersing the students in the reality and scope of the problem will engage them in the learning of the science that follows.

Class 1: TEACHER PROCEDURE

Give the pretest to the class a day or two before you plan to begin the activity.

Preparation:

- Before class, tape the numbered "*Topical Barometer*" sheets to the wall in an area that will allow students enough room to decide where they fall in the range and place their sticky-note in that space. For an explanation of the topical barometer strategy, see Appendix B.

- Have the computers set to show the video clips "Rooftops" http://www.epa.gov/radon/images/rooftops_psa.mpeg and "People on the Street" http://www.epa.gov/radon/images/people_eng_30.mpg. Arrangements should be made for the students to use the computers to access the internet so there is a minimum of time lost in logging on and reaching the website. Alternatively, these video clips may be shown on a projector to the entire class.

- Prepare one copy of the following handouts for each student: **KWL** sheet, **Focused Write** (2 sided), and **Where is radon contamination a problem?** (2 sided).

Activity #1: Topical Barometer ________________________ 3 minutes

1. Distribute one sticky-note to each student; have them write their initials or first name on the note.
2. Read the following statement:

   "Radon gas is a very serious threat to the health of thousands of Americans."

3. Ask students to think about their reaction to the statement and select the posted sheets that best represents where they fall in the continuum. Ask them to place their sticky-note on or near the sheet that best represents how they feel about the statement.

Activity #2: K-W-L ___________________________________ 12 minutes

For information on the K-W-L strategy, see appendix B.

1. Pass out the ***K-W-L*** sheet. Ask the students to turn the sheet over and listen closely as the teacher reads the following reading.

   "It is the fall of 1984 in Boyertown, Pennsylvania. In general, things were fairly quiet in the town in the eastern section of the state.

   The Watras family had been living in their home for about a year. Stanley, the father, was an engineer working on the construction of a nuclear power plant. The construction site at the plant had all of the up-to-date safety precautions in place to protect the workers as well as the environment. One of the safety devices in place was a radiation sensor placed in the entrance to the plant. It was designed to monitor workers going out of the plant to be sure that they did not

become contaminated with radioactive materials in the plant and then leave and spread that material to their homes and families. All of the employees had to pass by one of the sensors on their way *into* and out of the facility.

One morning, on his way *into* work, Stan set off the radiation detector. It was a kind of bizarre and mysterious event. The authorities were baffled as to what was going on. It seemed that he was contaminated with radioactive material and then bringing it into work." (Breecher 11; Shabecoff 1)

2. Ask the students to complete the 'K' column by making a list of what they know from what they heard. (Allow a short time to write and allow a couple volunteers to share.

3. Then ask students to fill in the 'W' column with what they would 'want to know' if they were trying to solve this problem. Again, allow a short time to write and allow a couple volunteers to share with the class before you continue reading.

"Mr. Watras was also confused and he asked the company to test his home. They agreed and the tests showed very high radon levels in his living room. Their results were 16 "working levels" of radon. This is a unit used by the Government to measure exposure of uranium miners to radon gas. The Environmental Protection Agency recommends radiation levels of no more than two one-hundredths of one working level. The reading of 16 working levels was the highest ever found in the United States from radon contamination. The results were later confirmed by the state and the E.P.A. tests as well.

On the advice of the state environmental agency, the Watras family moved out of their new home. Exposure to those levels of radon raised their risk of contracting lung cancer within a few years to an extremely high level.

The source of the radon in their home was from the rock and soil below the home that contained small amounts of uranium. Radon is one of the elements that form as uranium decays. Radon itself ultimately becomes other radioactive elements that can collect in homes where people can inhale them and the particles tend to lodge in their lungs. Over time, the radiation given off from the particles can cause lung cancer." (Shabecoff 1)

4. Ask students to complete the 'L' column of the table by listing what they have 'learned' from the activity.

5. Invite students to come up with other questions that they might have that are still unanswered at this point in the lesson. Have them write those questions on the back of the form and hang on to them. Hopefully they will be answered by the time we are through, or the questions can be the start of a short, individual research project.

Activity #3: Focused Writing Activity 10 minutes

For information on the Focused Writing Activity, see Appendix B.

1. Pass out the ***Focused Write*** student sheet (two-sided).

2. Show the video "Rooftops" (30-second video clip available at http://www.epa.gov/radon/images/rooftops_psa.mpeg). Show the video clip again and then ask the students to take 2-minutes to write on the front of the paper. At the end of the time, ask the students to turn their papers over and quickly answer the 4 questions at the top from what they remember from the clip. (You may choose to show it again to let the students check their memories and self-correct.)

3. Show the video clips of "People on the Street" (30 second video clip available at http://www.epa.gov/radon/images/people_eng_30.mpg) answering questions about the threat from radon gas. Allow a minute or two for students to complete their reactions to the clips.

4. If time, allow student volunteers to share any of their reactions or answers they have written. (May be done in pairs, small groups or the entire class.)

Activity #4: GIS website exploration 20 minutes

1. Pass out **Where is Radon Contamination a Problem?** sheet for the GIS activity. Students should be able to access the website: http://www.epa.gov/radon/zonemap.html

2. Ask students to read through the first section of the website and navigate to where they can determine the radon levels in various areas. The locations on the student's sheet can be adjusted if they are not applicable to any individuals. (The goal is to have them recognize the geographical extent of the problem. The value of using GIS as a tool to display information is also an important goal.)

Class 2: BACKGROUND FOR TEACHERS

The electromagnetic spectrum includes all the types of radiation from long-wave radio waves through very short-wave gamma radiation. The higher the frequency, the shorter the wavelength becomes. Also, the higher frequency radiations have higher energy and can cause damage to living cells. Radiation that is able to do this is called ionizing radiation. Gamma rays are pure energy that is released from some nuclear sources.

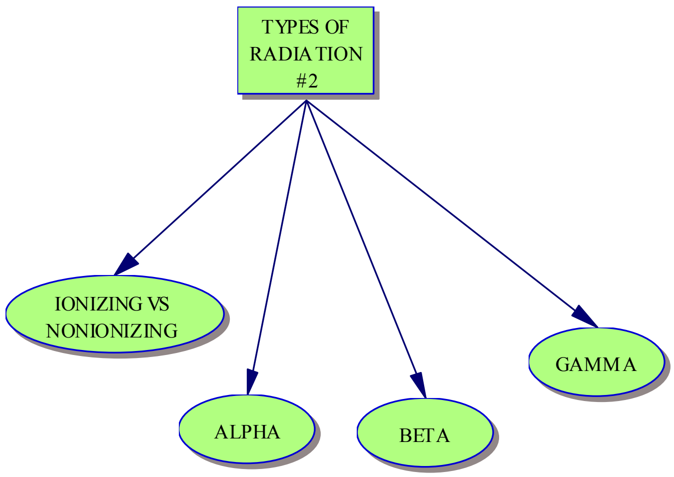

Figure 2: Diagram showing types of radiation and radiation particles. By K.L., 2006

In addition, alpha and beta particles can be released from the natural change of one unstable isotope to another. These particles have measurable mass and charge and can also do damage to living cells. It is important to recognize the different types of radiation when exploring the environmental hazards posed by a radioactive material like radon. The PowerPoint presentation (**Transmutation and Decay Series**) describes electromagnetic radiation as well as the radioactive particles and their respective penetrating power.

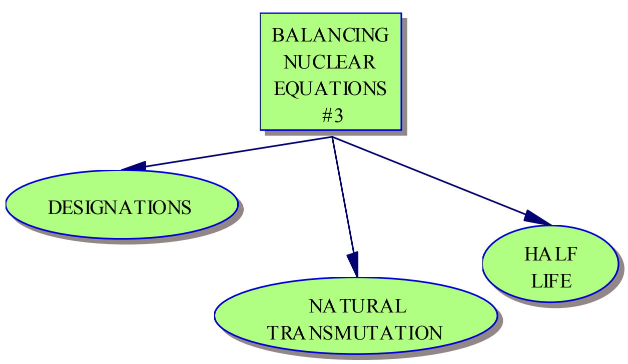

Figure 3: Diagram showing science component when writing and balancing nuclear reactions. By K.L., 2006

Chemical equations are short-hand ways for chemists to describe changes in matter as substances interact and bonds are formed and broken. A different, but in many ways similar, type of equation is used to describe a nuclear reaction. Because the changes involve the atomic nucleus, it is necessary to include the number of protons--the atomic number, as well as the total number of protons and neutrons present--the mass number. The mass number is used to designate the various isotopes that may be stable or unstable. Because the number of neutrons can vary in the same element, the mass number will be different for different isotopes. The unstable ones are called radioactive. They emit radiation as they go through a series of changes until they ultimately become a stable isotope of a different element.

It is the change of one element to another that identifies a nuclear reaction as a transmutation. Natural transmutation is a spontaneous release of radiation and outside conditions do not affect what type of radiation will be given off or the rate at which it will occur. It is this constant rate of change or decay that is the basis for using the ratios of certain isotopes present to determine the age of a fossil or a rock. The time required for one half of a sample to change to another isotope is called its half-life and it is unique and unchanging for that radioisotope. The time required for a radioactive substance to undergo transmutation can be an important factor in assessing its environmental dangers and risks.

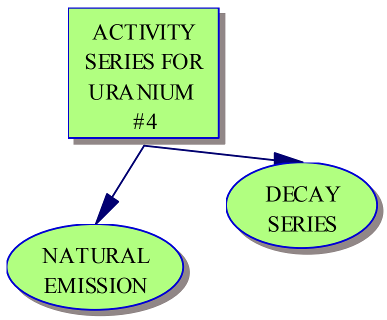

Figure 4: Diagram shows that uranium undergoes a natural series of changes as it gives off radiation in its decay series. By K.L., 2006

Each radioisotope goes through a specific series of changes as it decays. Isotopes of one element disappear and isotopes of a different element come into existence as a radioactive particle is given off.

Uranium is a radioactive element that exists naturally in rocks and has a very long half-life. Nevertheless, individual atoms are unstable and eventually emit an alpha particle to become an unstable atom of the element thorium. This new radioisotope will eventually release a beta particle to become yet another unstable atom of a different element. This sequence is called a decay series.

The decay series for uranium-238 consists of about 15 steps. It is completed only when a stable isotope of lead forms. (It should be noted that it is the third lead isotope that is formed before it finally reaches a stable isotope.) As these steps begin, the isotopes that form, although unstable, are nonetheless bound into the solid matrix of the rock or mineral containing the uranium. They may be potentially harmful, but at least they are not free to move about the environment. This all changes when the parent isotope for radon-222 releases its alpha particle. As the relatively heavy alpha particle is released in one direction, the rest of the atom-- the radioactive radon-- will recoil in the opposite direction as a gas atom. If that direction takes it away from the surface of the mineral, it can escape and become free and able to become a potential hazard to environmental health.

Because several more isotopes in the sequence are unstable, it is not just the one alpha particle that poses the danger. Subsequent radioisotopes, radon progeny, will release their radiation as they too undergo transmutation.

Class 2: TEACHER PROCEDURE

Preparation:

- Review the Think-Pair-Share strategy described in Appendix B.
- Make copies of the set of **Transmutation Practice Sheets A-F.** To determine the number of copies of the series needed, divide the number of the students in the class by 12 and round up. For example, for a class of 30 students you will need 3 sets of Transmutation Practice Sheets. You will need to be sure to have at least one set (A-F) per class so that you will get the complete decay series that you are trying to show. You will distribute ONE transmutation sheet (not one set) to each pair of students. Each sheet will accommodate two students (a pair) who will team up and work on the same transmutations; have the students fold and tear the sheet in two.
- For each student, make one copy of the **Graphing Natural Decay Series--Uranium-238 disintegration series** (2-sides) and one copy of the **Individual Practice Sheet for U-235** (2-sides).
- Optional but recommended: For each student, provide copies of the **Transmutation and Decay Series** PPT slides printed as handouts (3 per page with note area) so that the students can use them as note sheets to accompany the PowerPoint presentation and a reference as they work in class
- Provide 2-3 sticky-notes for each student to write the result of their transmutation. They will also need a marker so that the class will be able to see their answer on the sticky-note.
- Before class set up the computer to show the PowerPoint "**Transmutation and Decay Series**" on nuclear notations and equations.
- Make a large version of the Uranium-238 Disintegration grid drawn on poster/chart paper. Tape this to the wall in an area that is accessible to the students.
- Students should have a periodic table with symbols and names.

Activity #5: Think-Pair-Share 6 minutes

1. Pass out the PowerPoint note sheets if you plan to provide them to the class. (If not, the students should have some method to take notes on what is being presented.). Show the PowerPoint "**Transmutation and Decay Series**" up to slide 20. The presentation progresses through the material slowly, giving examples.
2. When the students have been shown how to use an alpha or beta emitter to determine the products of the transmutation (slide 20), pass out one of the **Transmutation Practice Sheets A-F** to each pair of students. Again, be sure that you have a full selection of sheets A through F distributed to students. Have the students fold and tear the sheet in two and each work on the two transmutations individually.

3. When individual students have finished they should pair up and compare their answers. Resolve any differences and be sure that they have followed the rules to determine the products correctly.
4. When they arrived at consensus for answers, each student writes one of the new isotopes on the sticky-note. (There should be at least one sticky-note for each transmutation done by the entire class.)

Activity #6a: Linear Display of Decay Series 4 minutes

1. The teacher should write a different sticky-note for each of the first three notations in the decay series: U-238, Th-234 and Pa-234. The first two transmutations are completed together as examples in the PowerPoint and the product is Pa-234 (slide 20).
2. Point out to students that the product of every transmutation should be the starting point of a different transmutation given. Place the sticky-notes for U-238, Th-234 and Pa-234 in a row from left to right to show the sequence allowing enough space for students to each add their sticky-note to the pattern. The student with Pb-206 will be the end of the series—a stable isotope.
3. Ask students to work together to put their sticky notes in the proper location on the posted U-238 disintegration series. (Do not show slide 23 yet; it shows the completed series.) It is important for students to see there is a pattern to this and that uranium does not turn directly into lead, as many think. In fact, not all isotopes of lead are stable. Verify the sequence with slide 23 and let students check their results.

Activity #6b: 2-D Display of Decay Series

1. Pass out the **Graphing Natural Decay Series--Uranium-238 disintegration series** sheet to each student.
2. Have them form pairs again and allow them to work together to change the linear display into a 2-D grid to show the difference between an alpha and a beta transmutation.
3. As the students figure out the pattern, allow them to go up to the wall grid and set up the scales and then move the sticky-notes from the line onto the grid.
4. Students then answer the questions on the U-238 sheet.

Activity #7: Individual Practice

Pass out the **Individual Practice Sheet for U-235** for students to complete for homework.

Day 3: TEACHER BACKGROUND

It is necessary to evaluate the risks and dangers of environmental hazards. The risk of experiencing adverse affects from a toxic material will depend on the amount, or concentration, of the material as well as the duration of the exposure to the individual.

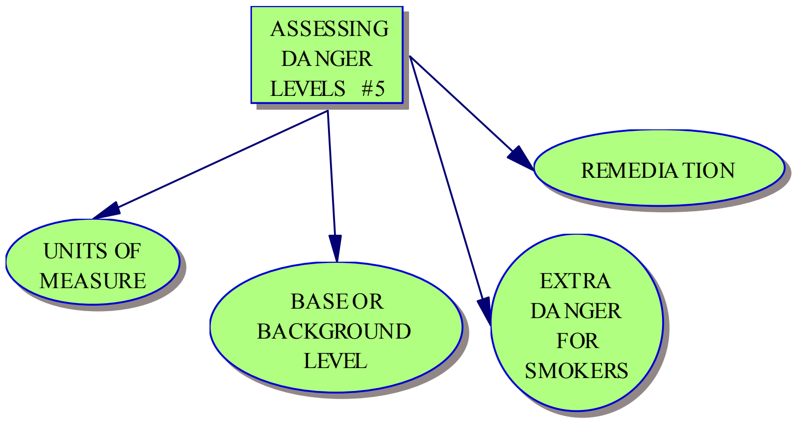

Figure 5: Diagram showing units of measure and environmental dangers associated with radon gas. By K.L., 2006

It is necessary to evaluate the risks and dangers of environmental hazards. The risk of experiencing adverse affects from a toxic material will depend on the amount, or concentration, of the material as well as the duration of the exposure to the individual.

Measuring concentration often requires understanding a new unit of measurement to describe how much of the toxic material is present in a unit of space or volume. Radon concentration is often expressed in picocuries per liter. The prefix *pico-* designates an amount equal to one millionth of a millionth, or 10^{-12}, of something. This is how many radioactive particles are being released in each liter of air containing radon.

Aspects of the project and references to the half-life of radioisotopes make this an excellent lead-in to the continuation of nuclear chemistry.

Day 3: TEACHER PROCEDURE

Preparation

1. Purchase radon testing kits from local stores or order online. Ideally you would order several different kinds.
2. Before class, open the radon test kits and make enough copies of the directions to give to each student who will be using each kit.
3. Have one copy of the EPA "Citizen's Guide to Radon" for each student. To order copies please ask for "**A Citizen's Guide to Radon**" EPA document number 402-K-02-006, Revised September 2005 by contacting **IAQ INFO**, P.O. Box 37133, Washington, DC 20013-7133 or calling **1-800-438-4318/**703-356-4020 or (fax) 703-356-5386 or email iaqinfo@aol.com You can also download and print copies of pdf file for this document at www.epa.gov/radon/images/citizensguide.pdf.
4. Run off enough **Aunt Gladys Letter Activity** sheets for each student (2-sided). In addition, there are five different test results from the hypothetical testing company. Make enough copies of these so that each student will randomly get one of the selection of test results. Put the letter and test result sheet in an envelope for each student. (Note: The author credits Linda Padwa at Stony Brook University for submitting the Aunt Gladys letter.)

Activity #8: Flowchart to Use Radon Test Kit

1. Divide the students into groups, depending on how many actual radon test kits are available.
2. Pass out a copy of the directions to each student. Students should read through the directions individually and then work in groups to create a flowchart to show the sequence of steps required to do the test. This flow chart should include information on selecting a location to place the test, determining how long to leave it in place and how to package and send it in to the laboratory. This is the lesson to be learned by this activity. Actually conducting a radon test in the school and having the students determine where, when and how to do it is an excellent exercise. Depending on how many tests are available, the units may be sold/donated/raffled to students to conduct their own radon tests.

Activity #9: Dear Aunt Gladys Letter

1. Pass out copies of the "Citizen's Guide to Radon" from the EPA to the students. This 16-page color booklet covers many aspects of the risks of radon in the environment. Allow the students to look through the booklet (you may choose to use the PowerPoint that shows each page and go through it as a group or allow the students to look at specific pages).
2. Pass out envelopes with Aunt Gladys letter and the test results. Allow students to read through the letter, look at the test results and read the directions. They will need to use the booklet to research what the test results mean (to smokers and non-smokers) and make a thoughtful recommendation to dear Aunt Gladys. The response letter written by each student can serve as an effective evaluation of what they learned from the activity.

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Take the National Radon Test: Man on the Street. 2000. Environmental Protection Agency. 21 Aug. 2006 <http://www.epa.gov/radon/images/radon.mpg>.

Additional Resources

New York State Radon Program: http://www.nyradon.org/. This organization provides information for students, teachers, and parents to learn about radon, including a program that provides free radon detectors to science classes.

New York State Learning Standards and Performance Indicators:

Key Idea 3: Matter is made up of particles whose properties determine the observable characteristics of matter and its reactivity.

Performance Indicator 3.1: Explain the properties of materials in terms of the arrangement and properties of the atoms that compose them.

Major Understandings:

- 3.1g The number of protons in an atom (atomic number) identifies the element. The sum of the protons and neutrons in an atom (mass number) identifies an isotope. Common notations that represent isotopes include: ^{14}C, $^{14}_{6}C$, carbon-14, C-14.
- 3.1p Spontaneous decay can involve the release of alpha particles, beta particles, positrons, and/or gamma radiation from the nucleus of an unstable isotope. These emissions differ in mass, charge, ionizing power, and penetrating power.
- 3.1y The placement or location of an element on the Periodic Table gives an indication of the physical and chemical properties of that element. The elements on the Periodic Table are arranged in order of increasing atomic number.

Key Idea 4: Energy exists in many forms, and when these forms change, energy is conserved.

Performance Indicator 4.4: Explain the benefits and risks of radioactivity

Major Understandings:

- 4.4a Each radioactive isotope has a specific mode and rate of decay (half-life).
- 4.4b Nuclear reactions include natural and artificial transmutation, fission, and fusion.
- 4.4c Nuclear reactions can be represented by equations that include symbols which represent atomic nuclei (with mass number and atomic number), subatomic particles (with mass number and charge), and/or emissions such as gamma radiation.

Key Idea 5: Energy and matter interact through forces that result in changes in motion.

Performance Indicator 5.3: Compare energy relationships within an atom's nucleus to those outside the nucleus.

Major Understandings:

- 5.3a A change in the nucleus of an atom that converts it from one element to another is called transmutation. This can occur naturally or can be induced by the bombardment of the nucleus with high-energy particles.

APPENDIX A – Student Handouts

1

STRONGLY AGREE

2

AGREE

3

NEUTRAL

4

DISAGREE

5

STRONGLY DISAGREE

Student Activity #2: **K-W-L Chart** NAME ____________________

K (What I Know)	W (Want to Know)	L (What I Learned)

Student Activity #3 Name…………………………………………………….

Focused Write (2-minute on the clock)

Watch the short video clip called "Rooftops." Summarize the information shared in the clip and predict what you think may be happening in this situation.

Who produced the video clip?
Who is sending a message to the American people?
What is the message being sent?
Why do you think this type of media campaign would be produced?

Watch the clips of "folks on the street" as they answer questions about Radon gas. What are your reactions after watching these clips?

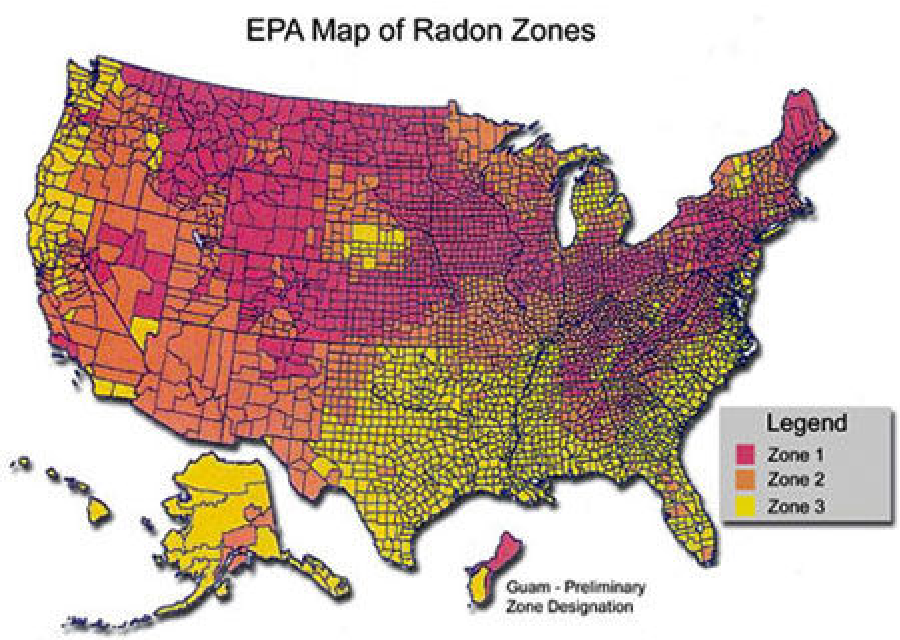
Student Activity #4 Name………………………………………………………………

Where is radon contamination a problem?

Scientists have learned the value of displaying and sharing information in more visual ways. Large amounts of data can now be built into maps using GIS technology. Measurements are taken at locations across a region and then the software produces a map showing geographic relationships.

Information on radon concentration is now available on the internet at the following website:

USGS Website for radon concentrations:
http://www.epa.gov/radon/zonemap.html



Visit the website and look at the range of measurements shown on the map.

Answer the following questions:

How widespread is radon distribution in the United States? ____________________

____

Use the website to find the radon concentration in

- your home county ______________
- where your grandparents live ____________
- where you go on vacation ____________
- where you are considering attending college____________
- where the Watras home was in Eastern Pennsylvania ________________

(*you may substitute any other type locations if one of the above does not apply to you)

What are the units of concentration used on this map? ___________

The EPA suggests that the every home should be checked, even though the amounts shown for the entire county are in the low, acceptable range. Why do you think this might be necessary?

____
____
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____

Look closely at the map of the United States shown on the website. The map is designed to make it easier for you to find a pattern in the data. Find and describe a pattern shown on the map.

____
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TRANSMUTATION PRACTICE SHEET A

Radon - 222 alpha emitter
Bismuth – 214 beta emitter

TRANSMUTATION PRACTICE SHEET A

Radon - 222 alpha emitter
Bismuth – 214 beta emitter

Think-Pair-Share

TRANSMUTATION PRACTICE SHEET B

Protactinium – 234m   beta emitter
Radium – 226   alpha emitter

TRANSMUTATION PRACTICE SHEET B

Protactinium – 234m   beta emitter
Radium – 226   alpha emitter

Think-Pair-Share

TRANSMUTATION PRACTICE SHEET C

Polonium - 214 alpha emitter
Bismuth – 210 beta emitter

TRANSMUTATION PRACTICE SHEET C

Polonium – 214 alpha emitter
Bismuth – 210 beta emitter

Think-Pair-Share

TRANSMUTATION PRACTICE SHEET D

Uranium – 234   alpha emitter
Lead – 210   beta emitter

TRANSMUTATION PRACTICE SHEET D

Uranium – 234   alpha emitter
Lead – 210   beta emitter

Think-Pair-Share

TRANSMUTATION PRACTICE SHEET E

Lead – 214	beta emitter
Polonium – 218	alpha emitter

TRANSMUTATION PRACTICE SHEET E

Lead – 214	beta emitter
Polonium – 218	alpha emitter

Think-Pair-Share

TRANSMUTATION PRACTICE SHEET F

Polonium - 210   alpha emitter
Thorium - 230   alpha emitter

TRANSMUTATION PRACTICE SHEET F

Polonium – 210   alpha emitter
Thorium – 230   alpha emitter

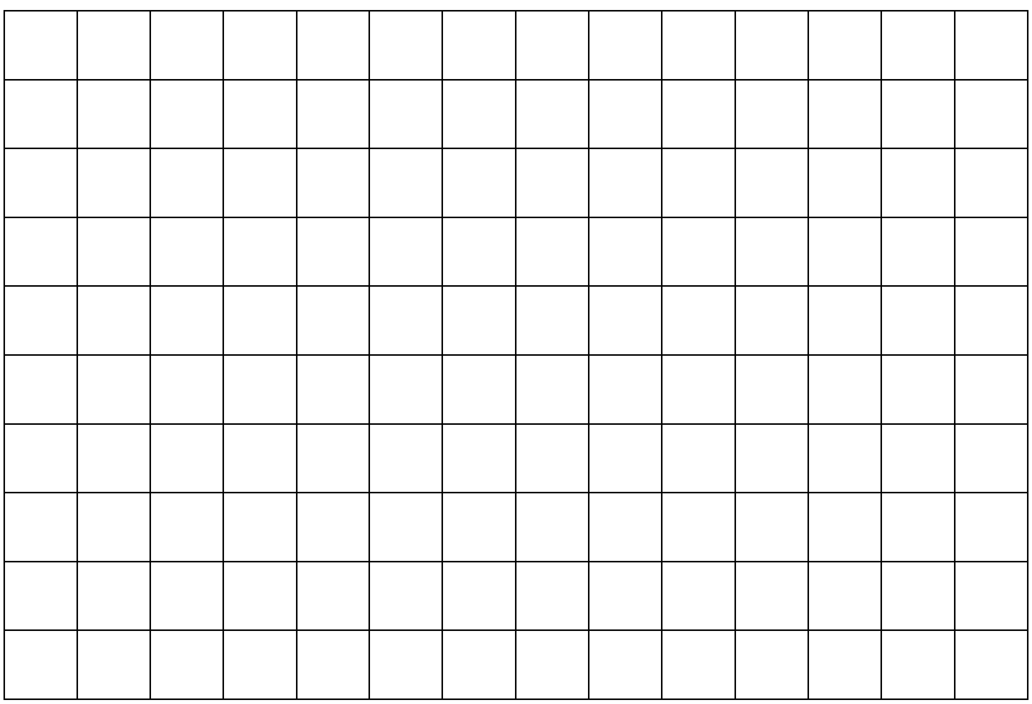
Student Activity #6 Name …………………………………………………….

Graphing Natural Decay Series

Examine the Post-It notes that indicate the range of atomic numbers of the radioisotopes in the uranium-238 decay series. Also look at the range of mass numbers that is included in this same list of radioisotopes.

Use the following grid to plot the atomic number (x-axis) vs. the mass number (y-axis). Label each axis and select an appropriate scale to include the necessary range.

URANIUM-238 DISINTEGRATION SERIES



Focus questions:

How does this picture of the decay series differ from the straight-line sequence we put on the wall after the activity?

____
____
____
____

What happens to the graph when a beta particle is released from a radioactive nucleus?

____
____
____
____

What are the advantages of showing the decay series in a graph form?

____
____
____
____

Student Activity #7 Name ……………………………..……………

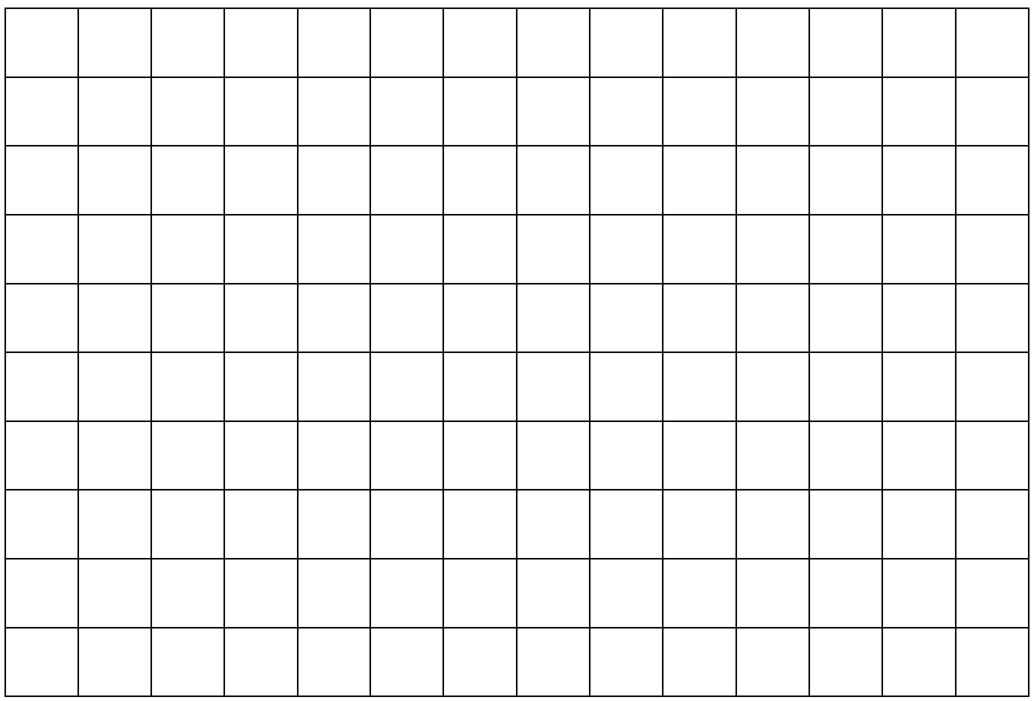
Individual Practice: U-235 Decay Series

Directions:
In the space provided, complete the transmutation that each isotope will undergo in the decay series. Starting with U-235, the isotope product of each transmutation will be the starting point of another given transmutation.
Use the grid provided on the back to create the 2-D decay series for U-235.

Isotope	Decay Mode	Transmutation
Uranium-235	Alpha	
Polonium-215	Alpha	
Actinium-227	Beta	
Lead-211	Beta	
Thorium-227	Alpha	
Actinium-227	Alpha	
Radon-219	Alpha	
Thorium-231	Beta	
Francium-223	Beta	
Thallium-207	Beta	
Lead -207	Stable	
Protactinium-231	Alpha	
Radium-223	Alpha	
Bismuth-211	Alpha	

Number the x-axis with the atomic numbers and the y-axis with the mass numbers to fit your results from the transmutations. Place a dot on the location for each isotope and use an arrow between each dot to show the sequence of the series.

URANIUM-235
DISINTEGRATION SERIES



How is this decay series similar to that of U-238? How is it different?

____

____

____

____

Are any of the isotopes common to both series? Does radon show up in this series as well?

____

____

____

Student Activity #9

Aunt Gladys Letter

Dear Chris,

It has been a busy summer here for your Uncle Benny and me. It seemed to take forever to get over that sickness we caught on the Jamaican cruise we were on last spring. We also finally got around to checking our new house for radon gas. We always thought that radon is only a problem in some parts of the country. Uncle Benny heard that scientists are not even sure that radon is a real health risk.

Anyway, the folks at the real estate office suggested that it would be a good idea to find out if we have it in our house or not. They said that several people in the area had high levels and they had to do some things to their house to make it safe. Uncle Benny and I have been here for about 8 months and we have not noticed any smells or stains that seem poisonous.

We just got the results back and I have to confess that I really don't understand this science stuff very well and your Uncle Benny is no help either. I remembered that you told us you were going to be taking Chemistry in high school this year from that smart teacher and I knew that you would be the best choice to help us out. I have put a copy of the test results in the envelope with this letter. We know you can tell us what it means and give us some advice if there is something we should do.

We are looking forward to seeing you over the holidays again. I know you will let us know as soon as you can. Thanks for your help,

Love,

Aunt Gladys

Aunt Gladys Activity:

Read Aunt Gladys' letter carefully then look over the test results that they received. Your job is to go through the test results and evaluate the results based on the EPA recommendations in their"Citizen's Guide to Radon" booklet. You then need to write a letter back to them addressing their concerns and questions. Remember that Aunt Gladys and Uncle Benny need their explanations very simple and basic. It is important, however, to be sure that you are complete and accurate.

Also, remember that Uncle Benny started smoking when he was much younger and has not been able to quit; he still smokes about a pack of cigarettes each day. It is important to point out if there are any differences in their risk to radon. They also believe some myths that are very common when dealing with radon. Be sure to let them know the current scientific facts and opinions.

Aunt Gladys has put you in a position of real responsibility and has essentially put their future health in your hands. Please take this trust seriously. Your advice to them should be based on what you have learned over the last few days about the topic.

NRT

Northeast Radon Testing, Inc.

Fast Accurate Reasonable

CUSTOMER: Benjamin and Gladys Airbreathers
25119 Loose Bedrock Drive
Granite Ledge, New York 11354

TEST DONE: Standard Long-term Test ("Alpha track" canister; 120 day)

TEST RESULTS: 0.87 pCi/L

NRT

Northeast Radon Testing, Inc.

Fast Accurate Reasonable

CUSTOMER: Benjamin and Gladys Airbreathers
25119 Loose Bedrock Drive
Granite Ledge, New York 11354

TEST DONE: Standard Long-term Test ("Alpha track" canister; 120 day)

TEST RESULTS: 1.61 pCi/L

NRT

Northeast Radon Testing, Inc.

Fast Accurate Reasonable

CUSTOMER: Benjamin and Gladys Airbreathers
25119 Loose Bedrock Drive
Granite Ledge, New York 11354

TEST DONE: Standard Long-term Test ("Alpha track" canister; 120 day)

TEST RESULTS: 3.49 pCi/L

NRT

Northeast Radon Testing, Inc.

Fast Accurate Reasonable

CUSTOMER: Benjamin and Gladys Airbreathers
25119 Loose Bedrock Drive
Granite Ledge, New York 11354

TEST DONE: Standard Long-term Test ("Alpha track" canister; 120 day)

TEST RESULTS: 5.94 pCi/L

NRT

Northeast Radon Testing, Inc.

Fast Accurate Reasonable

CUSTOMER: Benjamin and Gladys Airbreathers
25119 Loose Bedrock Drive
Granite Ledge, New York 11354

TEST DONE: Standard Long-term Test ("Alpha track" canister; 120 day)

TEST RESULTS: 10.28 pCi/L

APPENDIX B - Teaching Strategies

Topical Barometer

This strategy allows students to visually sort where they are on a spectrum. Students may discuss why they chose their position.

Strongly Agree	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**

A linear representation of the topical barometer enables both students and teachers to see relative positions of students on an issue. This can be done on a chalk board or written on adding machine tape affixed to the wall.

To use the topical barometer, each student writes his/her name on a post-it note then places it on the continuum in a pace that best represents his/her point of view on an issue. Once students see where they stand with respect to one another, the teacher can divide students into groups representing different viewpoints on an issue to carry on a structured academic controversy. Following the structured academic controversy, students can move their post-it notes, if desired.

Inspired by Crown Point Constructivist Team, 2002

KWL and Variations

(What I Know, Want to Know, What I Learned)

KWL is a learning strategy and graphic organizer used to introduce new material. The KWL is used to predict and connect prior knowledge. KWL can be used to brainstorm prior knowledge, preview vocabulary and concepts, and to tell the student to recall what they have read. This learning strategy focuses the student on the assigned text and allows the teacher to model what effective readers do with respect to content in subject areas.

KWL:

- encourages curiosity about the topic
- raises the student's motivation
- gives the student a focus for reading, writing, and studying ("Want to Know")
- exposes the student's misconceptions so the teacher can plan appropriate interventions
- promotes active reading

How To Use It:

1. Three columns are drawn and appropriate headings added.
2. Students brainstorm what they know or think they know. Their thoughts are written in Column 1. Items are categorized.
3. Students write what they want to know in Column 2.
4. Students read assigned text.
5. Students identify what they learned and write this additional information in Column 3.
6. Students compare contents of Column 3 with Column 1 to find out if what they thought they knew was changed by anything they read.

K **(What I know)**	**W** **(Want to know)**	**L** **(What I learned)**

The KWL strategy can be modified to meet the objectives of the learning experience. Some examples of variations include:

- adding a fourth column such as “What Else They Want To Learn and How They Will Find Out” (KWLH) or “Where It Was Learned” (KWLW)
- construction of different headings for columns that align with new objective(s). For instance, a free writing KWL might look like this:

What You Understand	**Questions You Have**

Focused Free-Writing

Free-writing is uninterrupted writing during a pre-determined period of time, usually 3-5 minutes. A *prompt** is given to which the student writes down whatever he/she is thinking as quickly as possible. The student does not worry about punctuation, grammar, or style during the free-writing activity. The technique stimulates thinking. During free-writing the student taps into his/her imagination and knowledge base.

Focused-free writing provides specific directions or filters prompting the student to write about a specific topic. The topic can be created by the teacher or taken from a textbook, articles, the news, video, or a class discussion. Focused free-writing encourages the student to express ideas clearly.

Focused-free writing:

- should be done quietly and without interruptions
- may be written in notebooks, journals, or learning logs
- may allow the student time to summarize what he/she has written
- may lead to a class discussion on general statements

*prompt-a stimulus or cue that elicits a response

Think - Pair - Share and Think – Pair - Share/Square

According to many teachers, the simplest cooperative learning structure/strategy is "Think-Pair-Share." While both Spencer Kagan who originated this term and Jack Hassard (1996) call this cooperative learning strategy "Think-Pair-Share," you may know it as "Turn To Your Neighbor" (Lundgren, 1994) or "Turn-To-Your-Partner" (Johnson, Johnson, Holubec, 1991). "Think-Pair-Share" requires each student to think about and respond to a question, discuss answers in pairs, then share their own or a partner's answer with the whole class or another group. Variations include writing answers and reading the other's answer(s), or discussing answers and constructing an answer that incorporates the best of each of the partners' answers. Each student of the pair may be given a predetermined amount of time for sharing his/her response.

After a pair of students has shared responses, that pair pairs with another set of partners to form a square, "Think-Pair-Share-Square." Students share their answers with teammates rather than with the class. As above, several variations can be used to help students construct learning. The whole group may decide that an answer they construct from all of the individual answers is superior to any of the original responses. Squares may share answers with the whole class or not.

"Think-Pair-Share" and "Think-Pair-Share/Square" are effective instructional strategies that can be useful during any stage of a lesson, but are most frequently used during the first few minutes (anticipatory set/motivation) or last few minutes (closure/summary/application).

Kagan (1998) suggests use of these structures/strategies for developing thinking skills, promoting communication skills and encouraging information sharing. He considers these tools that access verbal/linguistic, interpersonal and intrapersonal intelligences.

APPENDIX C - Teacher Answer Keys

TEACHER Answer KEY FOR #3
Focused Write (2-minute on the clock)

Watch the short video clip called "Rooftops." Summarize the information shared in the clip and predict what you think may be happening in this situation.

Radon gas is a health hazard in many homes around the country. There is a contact number for more information. There are many homes that have the problem and there are things that can be done to make the homes safe.
Attempt to make people aware of the dangers of radon in their homes.

Who produced the video clip?
Who is sending a message to the American people?
What is the message being sent?
Why do you think this type of media campaign would be produced?

Produced by the Environmental Protection Agency, EPA, federal government,…

The EPA and the Surgeon General of the United States.

Radon is a very common problem that is endangering the health of many people and people should test for it and remediate if necessary.

It would only be produced if the problem was widespread; it is a national public service announcement. If people were not responding to other warnings, this would hopefully reach more people.

Watch the clips of "people on the street" as they answer questions about Radon gas. What are your reactions after watching these clips?

Reactions will vary.

Most people shown are not aware of the dangers of radon and how serious a problem it is.

TEACHER KEY FOR ACTIVITY #4

How widespread is radon distribution in the United States?
It is found in every state in the United States

Use the website to find the radon concentration in
all of these values will depend on where the student selects

- your home county
- where your grandparents live
- where you go on vacation
- where you are considering attending college
- where the Watras home was in Eastern Pennsylvania   expected over 4 pCi/L

(*you may substitute any other type locations if one of the above does not apply to you)

What are the units of concentration used on this map? picoCuries/Liter   pCi/L

The EPA suggests that the every home should be checked, even though the amounts shown for the entire county are in the low, acceptable range. Why do you think this might be necessary?

The soil and bedrock can change in very short distances and will not follow county lines. There may be factors around individual homes that would affect how radon would move through the soil and enter a home.

Look closely at the map of the United States shown on the website. The map is designed to make it easier for you to find a pattern in the data. Find and describe a pattern shown on the map.

There are many patterns. Any pattern that the student can point out and defend should be accepted.

TEACHER KEY FOR Activity #5

TRANSMUTATION PRACTICE SHEET A

Radon—222 alpha emitter
Polonium-218
Bismuth – 214 beta emitter
Polonium-214

TRANSMUTATION PRACTICE SHEET B

Protactinium – 234m beta emitter
Uranium-234
Radium – 226 alpha emitter
Radon-222

TRANSMUTATION PRACTICE SHEET C

Polonium -- 214 alpha emitter
Lead-210
Bismuth – 210 beta emitter
Polonium-210

TRANSMUTATION PRACTICE SHEET D

Uranium – 234 alpha emitter
Thorium-230
Lead – 210 beta emitter
Bismuth-210

TRANSMUTATION PRACTICE SHEET E

Lead – 214 beta emitter
Bismuth-214
Polonium – 218 alpha emitter
Lead-214

TRANSMUTATION PRACTICE SHEET F

Polonium -- 210 alpha emitter
Lead-206
Thorium -- 230 alpha emitter
Radium-226

TEACHER ANSWER KEY FOR ACTIVITY #6
Graphing Natural Decay Series

Place atomic numbers across the top as shown. Place mass numbers from 238 down to 206, with an increment of 4, along the vertical axis. Writing the symbol for each element from Pb to U on the line beneath its atomic number will help see which elements have multiple isotopes.

<u>Focus questions</u>:

How does this picture of the decay series differ from the straight-line sequence we put on the wall after the activity?

This arrangement shows how the atomic number and mass numbers change and how the same element can have more than one isotope in the same decay series. It also shows the difference between an alpha and beta emission on the isotope formed.

What happens to the graph when a beta particle is released from a radioactive nucleus?

There is a horizontal change along the same mass number to a different element with a larger atomic number.

What are the advantages of showing the decay series in a graph form?

It is much easier to see the incremental changes in the atomic number and the mass number. Alpha emission drops both atomic number and mass number in consistent way and beta emission keeps the same mass number. It is also easy to see the elements that have more than one isotope present.

Student Activity #7 Name ……………………………………………………….

Individual Practice: U-235 Decay Series

Directions: In the space provided, complete the transmutation that each isotope will undergo in the decay series. Starting with U-235, the isotope product of each transmutation will be the starting point of another given transmutation.
Use the grid provided on the back to create the 2-D decay series for U-235.

Isotope	Decay Mode	Transmutation
Uranium-235	Alpha	Thorium-231
Polonium-215	Alpha	Lead-211
Actinium-227	Alpha & Beta	Alpha to Francium-223 and Beta to Thorium-227
Lead-211	Beta	Bismuth-211
Thorium-227	Alpha	Radium-223
Radon-219	Alpha	Polonium-215
Thorium-231	Beta	Protactinium-231
Francium-223	Beta	Radium-223
Thallium-207	Beta	Lead-207
Lead -207	Stable	Stable
Protactinium-231	Alpha	Actinium-227
Radium-223	Alpha	Radon-219
Bismuth-211	Alpha	Thallium-207

For the graph, students should set up each axis like the one done in class and following directions.

How is this decay series similar to that of U-238? How is it different?

Both series start with uranium and end with lead by alpha and beta emissions. They do not have the same number of steps; they do not start and stop with same isotopes; one radioisotope has both an alpha and a beta decay.

Are any of the isotopes common to both series? Does radon show up in this series as well?

There are no isotopes common to both decay series; many of the same elements but different isotopes of those elements.

Radon does show up but as radon-219 rather than radon –222.

TEACHER ANSWER KEY FOR ACTIVITY # 9

Dear Aunt Gladys Letter

Students should respond in a letter that addresses the dangers of radon in the home. The myths that should be addressed are the fact that radon is found only in parts of the country and that scientists are undecided about the actual danger of radon. They should include the added concern for Uncle Benny's health because he is a smoker. They should use the chart in the EPA booklet and indicate how many more times likely he is to develop cancer because of his smoking. It is a stressor to the exposure of radon.

Depending on the hypothetical test result that they were given, they should respond using the EPA Guidelines. It is also important to recognize that any error made should be on the side of caution. It is unlikely that they would be able to lower the two smallest values (0.87 and 1.61 pCi/L) and the two highest values (5.94 and 10.28) should definitely be addressed. The middle value of 3.49 is below the EPA threshold so students could recommend either route, but with Uncle Benny's smoking, it would be more responsible to recommend action at that level as well.