**Nuclear Waste: How Will YOU Handle Our Excretions?   
Finding the exPotential**

****

Do you enjoy learning about science, the outdoors, animals, equipment, environmental issues, ecology or natural resources? Are you a student who is interested in learning about workings of the human mind, cultural differences, children, public and community service, relationships or teaching? Would you like to learn more about nutrition and food preparation, life-long fitness, mental and social health, science, and opportunities related to medical professions? Do you like being in classes that are activity-based that allow you to explore ideas and concepts? Are you interested in having teachers that value relationships and who will focus on connecting the coursework to your future pursuits?

**NGSS**

**2-PS1-1.** Plan and conduct an investigation to describe and classify different kinds of materials by their observable properties

**2-PS1-2.** Analyze data obtained from testing different materials to determine which materials have the properties that are best suited for an intended purpose.

**4-PS3-4.** Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.

**5-PS1-1.** Develop a model to describe that matter is made of particles too small to be seen.

**5-PS1-3.** Make observations and measurements to identify materials based on their properties.

**HS-PS1-1.** Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.

**HS-PS1-8.** Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.

**Physics**

**NP.15.P.2** Predict the products of nuclear decay

**NP.15.P.3** Calculate the decay constant and the half-life of a radioactive substance

**NS.16.P.1** Describe why science is limited to natural explanations of

how the world works

**NS.16.P.3** Summarize the guidelines of science:

• results are based on observations, evidence, and testing

• hypotheses must be testable

• understandings and/or conclusions may change as new data are generated

• empirical knowledge must have peer review and verification before acceptance

**APES**

**IV. Land and Water Use:**

E. Mining (Mineral formation; extraction; global reserves; relevant laws and treaties)  
V. Energy Resources and Consumption  
D. Nuclear Energy (Nuclear fission process; nuclear fuel; electricity production; nuclear reactor types; environmental advantages/disadvantages; safety issues; radiation and human health; radioactive wastes; nuclear fusion)

**VI. Pollution:**A. Pollution Types

3. Water pollution

(Types; sources, causes, and effects; cultural eutrophication; groundwater

pollution; maintaining water quality; water purification; sewage

treatment/septic systems; Clean Water Act and other relevant laws)   
B. Impacts on the Environment and Human Health

1. Hazards to human health

(Environmental risk analysis; acute and chronic effects; dose-response

relationships; air pollutants; smoking and other risks)

2. Hazardous chemicals in the environment

(Types of hazardous waste; treatment/disposal of hazardous waste;

cleanup of contaminated sites; biomagnification; relevant laws)

C. Economic Impacts

(Cost-benefit analysis; externalities; marginal costs; sustainability)

**CCMS**

*Algebra II:*

**N.Q.2.2** Define appropriate quantities for the purpose of descriptive modeling.

**A.SSE.2.5** Use the structure of an expression to identify ways to rewrite it.   
**A.SSE.3.6** Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression*. c. Use the properties of exponents to transform expressions for exponential* functions.

**A.CED.1.10** Create equations and inequalities in one variable and use them to solve problems. Include equations arising from linear and quadratic functions, and simple rational and exponential functions.

**F.IF.4.16** For a function that models a relationship between two quantities, interpret key features of graphs and tables in terms of the quantities, and sketch graphs showing key features given a verbal description of the relationship.

**F.IF.6.16** Calculate and interpret the average rate of change of a function (presented symbolically or as a table) over a specified interval. Estimate the rate of change from a graph.

**F.IF.7.17** Graph functions expressed symbolically and show key features of the graph, by hand in simple cases and using technology for more complicated cases

**F.IF.8.17** Write a function defined by an expression in different but equivalent forms to reveal and explain different properties of the function.

**F.IF.9.17** Compare properties of two functions each represented in a different way (algebraically, graphically, numerically in tables, or by verbal descriptions).

**F.BF.1.18** Write a function that describes a relationship between two quantities

**F.LE.2.20** Construct linear and exponential functions, including arithmetic and geometric sequences, given a graph, a description of a relationship, or two input-output pairs (include reading these from a table).

**F.LE.4.20** For exponential models, express as a logarithm the solution to a\*bct = d where a, c, and d are numbers and the base b is 2, 10, or e; evaluate the logarithm using technology.

**F.LE.5.21** Interpret the parameters in a linear or exponential function in terms of a context.

**NGSS Science and Engineering Practices**

1. ASK QUESTIONS AND DEFINE PROBLEMS

2. DEVELOP AND USE MODELS

3. ANALYZE AND INTERPRET DATA

4. PLAN AND CARRY OUT INVESTIGATIONS

5. CONSTRUCT EXPLANATIONS AND DESIGN SOLUTIONS

6. USE MATHEMATICS AND COMPUTATIONAL THINKING

7. OBTAIN, EVALUATE AND COMMUNICATE INFORMATION

8. ENGAGE IN AN ARGUMENT FROM EVIDENCE

**Eight Standards for Mathematical Practices**

Standard 1: Make sense of problems and persevere in solving them

Standard 2: Reason abstractly and quantitatively

Standard 3: Construct viable arguments and critique the reasoning of others

Standard 4: Model with mathematics

Standard 5: Use appropriate tools strategically

Standard 6: Attend to precision

Standard 7: Look for and make use of structure

Standard 8: Look for and express regularity in repeated reasoning

**English Language Arts Practices**

E.1 They demonstrate independence.

E.2 They build strong content knowledge.

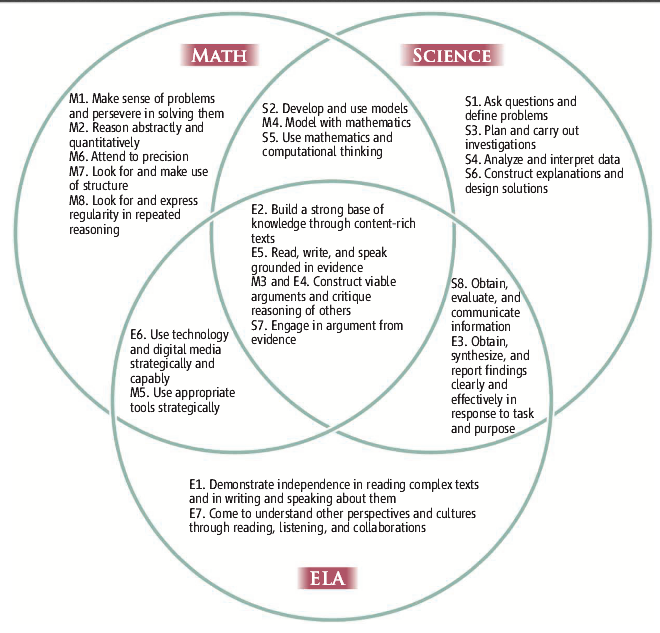
E.3 They respond to the varying demands of audience, task, purpose, and discipline

E.4 They comprehend as well as critique.

E.5 They value evidence.

E.6 They use technology and digital media strategically and capably.

E.7 They come to understand other perspectives and cultures.



**Level of complexity:** This investigation is designed for CREW students who are enrolled in Algebra II, Physics, and/or AP Environmental Science. We will discuss the investigation with CREW faculty during several collaborative planning periods. Pre-lab discussion with CREW students will take place in individual classes during regular schedule. The investigation itself will be conducted in one day during a modified schedule – SLC day. After the completion of the investigation, we plan to debrief with the other CREW faculty to revise the activity in preparation for the following year.

**Pre-lab instruction**

The concept of radioactive decay will be introduced and discussed in the class. The concept will be demonstrated by using a cloud chamber (<http://video.mit.edu/watch/cloud-chamber-4058/>). Teachers may want to plan ahead and reserve computers for students to perform their research.

**Information that may be useful for the instructor**

|  |
| --- |
| **Medical**  Radioactive [medical waste](http://en.wikipedia.org/wiki/Medical_waste) tends to contain [beta particle](http://en.wikipedia.org/wiki/Beta_particle) and [gamma ray](http://en.wikipedia.org/wiki/Gamma_ray) emitters. It can be divided into two main classes. In diagnostic [nuclear medicine](http://en.wikipedia.org/wiki/Nuclear_medicine) a number of short-lived gamma emitters such as [technetium-99m](http://en.wikipedia.org/wiki/Technetium-99m) are used. Many of these can be disposed of by leaving it to decay for a short time before disposal as normal waste. Other isotopes used in medicine, with half-lives in parentheses, include:   * [Y-90](http://en.wikipedia.org/wiki/Yttrium), used for treating [lymphoma](http://en.wikipedia.org/wiki/Lymphoma) (2.7 days) * [I-131](http://en.wikipedia.org/wiki/Radioiodine), used for [thyroid](http://en.wikipedia.org/wiki/Thyroid) function tests and for treating [thyroid cancer](http://en.wikipedia.org/wiki/Thyroid_cancer) (8.0 days) * [Sr-89](http://en.wikipedia.org/wiki/Strontium), used for treating [bone cancer](http://en.wikipedia.org/wiki/Bone_cancer), [intravenous injection](http://en.wikipedia.org/wiki/Intravenous_injection) (52 days) * [Ir-192](http://en.wikipedia.org/wiki/Iridium), used for [brachytherapy](http://en.wikipedia.org/wiki/Brachytherapy) (74 days) * [Co-60](http://en.wikipedia.org/wiki/Cobalt), used for brachytherapy and external radiotherapy (5.3 years) * [Cs-137](http://en.wikipedia.org/wiki/Cs-137), used for brachytherapy, external radiotherapy (30 years) |
| |  |  |  |  |  | | --- | --- | --- | --- | --- | | [**Long-lived**](http://en.wikipedia.org/wiki/Long-lived_fission_product)[**fission products**](http://en.wikipedia.org/wiki/Fission_product) | | | | | | **Prop: Unit:** | [**t½**](http://en.wikipedia.org/wiki/Halflife)[**Ma**](http://en.wikipedia.org/wiki/Million_years) | [**Yield**](http://en.wikipedia.org/wiki/Fission_product_yield) **%** | [**Q**](http://en.wikipedia.org/wiki/Decay_energy) **\*** [**KeV**](http://en.wikipedia.org/wiki/Kiloelectronvolt) | [**βγ**](http://en.wikipedia.org/wiki/Decay_mode) **\*** | | [99Tc](http://en.wikipedia.org/wiki/Technetium-99) | 0.211 | 6.1385 | 294 | β | | [126Sn](http://en.wikipedia.org/wiki/Tin-126) | 0.230 | 0.1084 | 4050 | β**γ** | | [79Se](http://en.wikipedia.org/wiki/Selenium-79) | 0.327 | 0.0447 | 151 | β | | [93Zr](http://en.wikipedia.org/wiki/Zirconium-93) | 1.53 | 5.4575 | 91 | βγ | | [135Cs](http://en.wikipedia.org/wiki/Caesium-135) | 2.3 | 6.9110 | 269 | β | | [107Pd](http://en.wikipedia.org/wiki/Palladium-107) | 6.5 | 1.2499 | 33 | β | | [129I](http://en.wikipedia.org/wiki/Iodine-129) | 15.7 | 0.8410 | 194 | βγ |  |  |  |  |  |  | | --- | --- | --- | --- | --- | | **Medium-lived** [**fission products**](http://en.wikipedia.org/wiki/Fission_product) | | | | | | **Prop: Unit:** | [**t½**](http://en.wikipedia.org/wiki/Halflife)[**a**](http://en.wikipedia.org/wiki/Annum) | [**Yield**](http://en.wikipedia.org/wiki/Fission_product_yield) **%** | [**Q**](http://en.wikipedia.org/wiki/Decay_energy) **\*** [**keV**](http://en.wikipedia.org/wiki/Kiloelectronvolt) | [**βγ**](http://en.wikipedia.org/wiki/Decay_mode) **\*** | | [155Eu](http://en.wikipedia.org/wiki/Europium-155) | 4.76 | .0803 | 252 | βγ | | [85Kr](http://en.wikipedia.org/wiki/Krypton-85) | 10.76 | .2180 | 687 | βγ | | [113mCd](http://en.wikipedia.org/wiki/Cadmium-113m) | 14.1 | .0008 | 316 | β | | [90Sr](http://en.wikipedia.org/wiki/Strontium-90) | 28.9 | 4.505 | 2826 | **β** | | [137Cs](http://en.wikipedia.org/wiki/Caesium-137) | 30.23 | 6.337 | 1176 | β**γ** | | [121mSn](http://en.wikipedia.org/wiki/Tin-121m) | 43.9 | .00005 | 390 | βγ | | [151Sm](http://en.wikipedia.org/wiki/Samarium-151) | 90 | .5314 | 77 | β | |

**Nuclear Waste: How Will YOU Handle Our Excretions?   
Finding the exPotential**

****

More than 30 years ago, nuclear plant owners and the Department of Energy (DOE) struck a deal. The owners agreed to pay into what’s called the Nuclear Waste Fund to help finance DOE construction of a permanent geological repository for nuclear waste by 1998. Fifteen years later there is still no repository, and the DOE has had to pay plant owners millions in damages for breach of contract. Meanwhile, nearly 70,000 metric tons of radioactive nuclear waste—the used, or “spent,” nuclear fuel—is building up at plant sites around the country, and nearly 75 percent of it is sitting in overcrowded cooling pools.

In this investigation, CREW teams will research a nuclear waste disposal problem. First your team will select a radioactive element and research from where it comes and its specific half-life. Then your team will simulate the element’s half-life and produce a mathematical model showing radioactive decay of their element over time. After presenting the results of their model, your team will research and present a solution to the radioactive waste disposal of their specific element.

**Procedure:**

Step 1 – Research the nuclear waste disposal issue and select a radioactive element to investigate.

Element selected \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Half-life of element \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Major source(s) of this waste element? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Step 2 – Collect the following equipment

- 100 M&M® (about two bags) – the nuclei

- 2 Container for the nuclei – decayed and not

- Cloth or box lid to hold nuclei

Step 3 – Half-life simulation

To do this, first, Determine if an up facing M represents decayed nuclei or not. Predict the number of nuclei that will remain after the first half-life cycle. Place all M&M’s in cup, and dump them into the box lid or onto the towel. Remove the decayed nuclei, and count the remaining nuclei. Record all data in the table below. Place the remaining nuclei back into the container, predict how many will remain after the next half-life cycle and repeat the above steps until no nuclei remain.

|  |  |  |
| --- | --- | --- |
| Time (half-life multiples) | Nuclei remaining | Prediction for next iteration |
| 0 | 100 |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |

What method did you use to predict the number of nuclei remaining after each half-life cycle? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

During the course of the investigation, did you modify your method at all? \_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

How well did your prediction match the results? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Step 4 – Graphical representation of data

Create a plot of these data.

What pattern do you see in the plot of your data? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Step 5 – Create a best fit mathematical model and state it below

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Identify all variables and constants and give both the magnitude and units for each of the constants.   
\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Step 6 – Create an exponential model of the form a\*bx and record it below. Identify the constants, magnitude and units for each.

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Step 7 – Re-write the above function using base ***e*** (Euler’s number) and record it below

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Teacher Note: Have one team collect data for the level of radiation (read from a Geiger Counter) as a function of distance from a radioactive source. Sources can be the chamber of a Smoke Detector, a Coleman mantle for a lantern, or some radiation source standard. Have this group model half-life as a distance, for their radiation source and create a mathematical model. Relate this graph and function to the half-life data.

Step 8 – Your team now has several mathematical models for the relation between the number of nuclei and time. Create a presentation to the class of your data using the Rubric below as a guide.

**Collection of Half-Life Data and Presentation – Rubric**

(to be fine-tuned in collaboration)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  | **Score** | | | |
| **Attribute** | Advanced | Proficient | Basic | Below basic | Non- responsive |
| Data Collection | - Discussion of patterns in the data, for example error, anomalies  - Multiple representations | - Table with data labels and units  - Significant digits  - Data represents the trend | - All present but some non-critical errors | - at least one critical piece is missing | - No products but a need for some self-esteem boost |
| Acoustical Presentation | - Flow between members is natural and contextual  - Demonstrated awareness of the audience and is responsive to them  - Volume, articulation, grammar and rate of speaking obviously enhances the presentation and message | - All members are equally active in presentation  - The presenters present to audience  -Volume, articulation, grammar and rate of speaking is appropriate | - All are present but some non-critical errors are present | - at least one critical piece is missing | - No products but a need for some self-esteem boost |
| Visual Products | - Multiple products are employed  -Transition between products is smooth and reflects practice and/or a deeper level of understanding | - Graph  - Data  - Image  - White Board, ppt, Nspire file, prezi etc.. | - All present but some non-critical errors are present | - at least one critical piece is missing | - No products but a need for some self-esteem boost |
| Math Model | - uses logarithms in their transformation  - Make connections to other scenarios that exhibit this behavior  -Elegant analysis of Constance of variables  -Discussion of the meaning of the exponents | - Units for Constants and Variables  - Two forms (a\*bx and a\**e*-kt) | - All present but some non-critical errors | - at least one critical piece is missing | - No products but a need for some self-esteem boost |
| Graph | - Additional functions and lines that identify points of interest | - Axes scaled correctly  - 75% rule  - Units on axes  - Appropriate Title  - Name of element and half-life | - All present but some non-critical errors | - at least one critical piece is missing | - No products but a need for some self-esteem boost |

Step 9 – Answer the following questions based on the presentations from each group.

How were the mathematical models in the form of a\*bx similar? different?  
\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

How were the mathematical models using ***e*** similar? different?  
\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

How did the data, graph and function for the radiation vs. time presentation relate to your radioactive waste element?   
\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**The Solution**

Step 10 -

**Presentation of Radioactive Waste Solution – Rubric**

(to be fine-tuned in collaboration)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Score** | | | | |
| **Attribute** | Advanced | Proficient | Basic | Below Basic | Non-responsive |
| Visual Products | - Multiple products are employed  -Transition between products is smooth and reflects practice and/or a deeper level of understanding | - Graph  - Data  - Image  - White Board, ppt, Nspire file, prezi etc.. | - All present but some non-critical errors are present | - at least one critical piece is missing | - No products but a need for some self-esteem boost |
| Discussion of Element | - Students demonstrate a thorough understanding of radiation  - Evidence of the placement of their element in the spectrum of the other radioactive elements | - Where it comes from  - How much waste we have to deal with  - Discussion of the radiation type | - All present but some non-critical errors are present | - at least one critical piece is missing | - No products but a need for some self-esteem boost |
| Solution | - Multiple solutions are discussed and the advantages/disadvantages of each.  - A discussion of what is currently done globally is presented and analyzed | - Method (recycle, burn, bury, etc.)  - Credulity | - All present but some non-critical errors are present | - at least one critical piece is missing | - No products but a need for some self-esteem boost |
| Acoustical Presentation | - Flow between members is natural and contextual  - Demonstrated awareness of the audience and is responsive to them  - Volume, articulation, grammar and rate of speaking obviously enhances the presentation and message | - All members are equally active in presentation  - The presenters present to audience  -Volume, articulation, grammar and rate of speaking is appropriate | - All are present but some non-critical errors are present | - at least one critical piece is missing | - No products but a need for some self-esteem boost |

If you started with a sample of 9,000 radioactive nuclei, how many would remain un-decayed after three half-lives?

If 177 un-decayed nuclei remained from a sample of 2832 nuclei, how many half-lives have passed?

How many half-lives would it take for 6.02 x 1023 nuclei to decay to 7% of the original number of nuclei?

Strontium-90 has a half-life of 28.8 years. If you start with a 20-gram sample of strontium-90, how much will be left after 230.4 years? Justify your answer.

**Student Handouts:** Create the necessary handouts you would provide to your students while they are gathering data and performing the project. This should include: instructions, safety statements, instructions for analysis, etc…

Students will count out 100 nuclei and then determine how a decayed nuclei would be represented (M up or down).

To help students understand the history of radioactivity, have them go to [Radioactivity: Historical Figures](http://www.accessexcellence.org/AE/AEC/CC/historical_background.html), on the Access Excellence Classic Collection site, to read about the contributions of Wilhelm Roentgen, Antoine Becquerel, Marie and Pierre Curie, and Ernest Rutherford.

As students read about these scientists, ask them to think about the following questions:

* What important discovery was made by Wilhelm Roentgen?
* What material did Antoine Becquerel work with in his own investigations of X rays?
* What did Becquerel discover through his experiments?
* What two elements were discovered by Marie and Pierre Curie?
* Why is Ernest Rutherford considered the father of nuclear physics? List Rutherford's major achievements.

<http://sciencenetlinks.com/lessons/radioactive-decay-a-sweet-simulation-of-a-half-life/>

**Math/Physics Concepts and Skills** – Make a list of physics and math concepts and skills necessary to complete the project. Define and explain the concepts and skills.

**Math/Physics** **Instructional Time Line** – Create an instructional timeline related to the math/physics concepts and skills necessary to complete this activity in your classroom. Identify when the skills and content are learned and/or introduced. Decide if they are pre-knowledge to if they will be taught/learned in your classroom.

**Math/Physics Language**– Make a list of terms and definition used in this activity that relate to each discipline (Math and Physics) individually. What are the differences and similarities? What could you do in your teaching to make sure students understand these differences and similarities?

**Instructor Reflection:** Develop a 1-page instructor’s self-reflection tool. This should give the instructor opportunity to reflect on the instructional process and the student action part of the project. What worked well? What should be improved? What could be changed and why? **Math/Physics Concepts and Skills** – Make a list of physics and math concepts and skills necessary to complete the tasks in the math modeling section and the physics investigation. Define and explain the concepts and skills.

|  |  |
| --- | --- |
| Math Concepts: | Math Skills: |
| Physics Concepts: | Physics Skills: |

**Math/Physics** **Instructional Time Line** – Create an instructional timeline to introduce the math and physics concepts and skills necessary to complete this activity in your classroom.

|  |  |  |
| --- | --- | --- |
| Order of concepts and skills | Math | Physics |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |

**Math/Physics Language Sheet** – Make a list of terms and definition used in this activity that relate to each discipline (Math and Physics) individually. What are the differences and similarities? What could you do in your teaching to make sure students understand these differences and similarities?

|  |  |
| --- | --- |
| Math | Physics |
| Differences | Similarities |

Notes: