Students' ideas about half-lives in an inquiry unit on radioactivity

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"Physics Survey" course at BHSU

Content goals:

- Differentiate types of radiation (α, β, γ, EM) by properties
- Quantized character of particle emission
- Define half-life operationally (**macroscopic** view)
- Understand decline of radiation and half-lives using a **microscopic** model.
- Apply radiation and half life ideas to questions on nuclear waste.
- others . . .

Ideas brought into class:

- Radiation is waves.
- Microwave ovens produce radiation
- Radiation contaminates other objects, making them radioactive.
- Radiation harms people through contamination.
- Radiation is continuous rather than intermittent.
- A radioactive object never gets weaker.
- Radiation decreases but it never goes away completely.
- Radiation treatment = chemotherapy.
- Half-life tells you when an object is no longer dangerous.
- Half-life is a video game.

Some activities:

Identify & count background radiation

Find natural & man made radioactive sources

Test the contamination theory

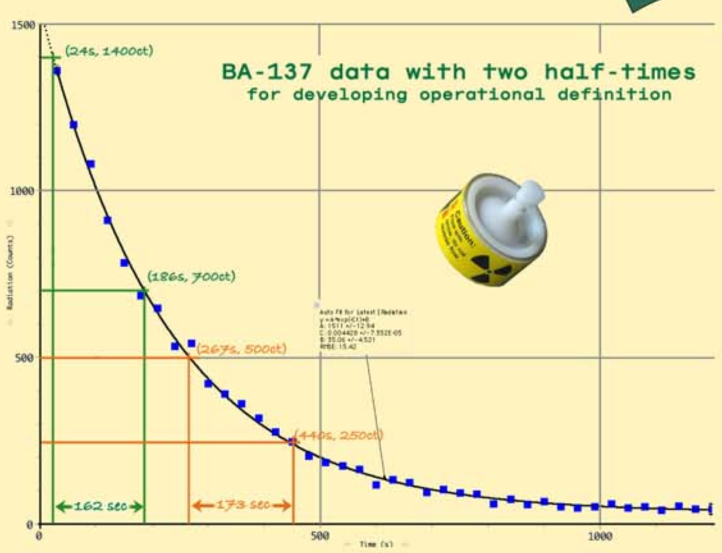
Distinguish ionizing from electromagnetic radiation

Distinguish α, β, γ by penetrating power

Distinguish α, β, γ by cloud chamber tracks

Measure declining radioactivity from Ba137, develop operational definition of half-life using a graph.

Develop a microscopic theory to explain the half-life graph via the Dice Game (see below)



Inferable Atom Rules (Target ideas):

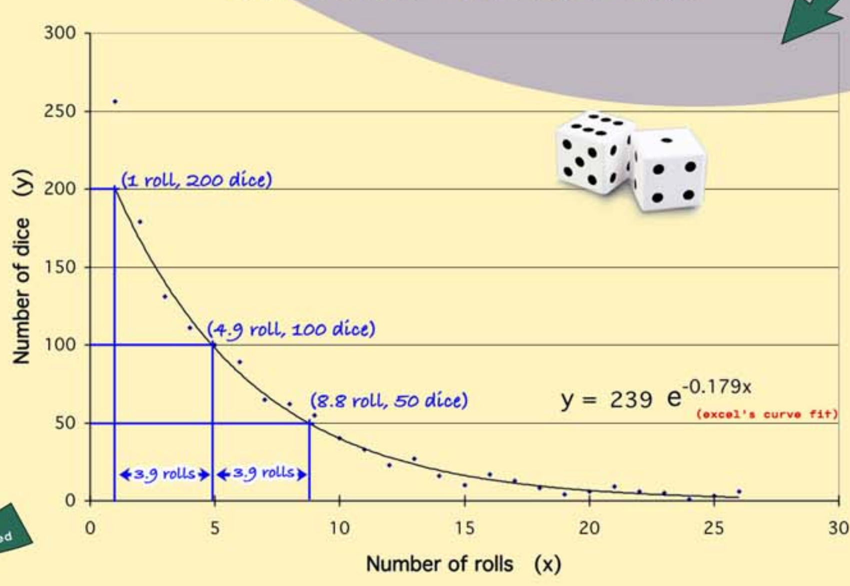
1. Each atom has a random chance of emitting radiation.
2. Each atom has a fixed probability of emitting in a certain time interval.
3. Once an atom emits it is out of the game.
4. With a large number of atoms, random variations average out.

Discussion required

The Dice Game rules:

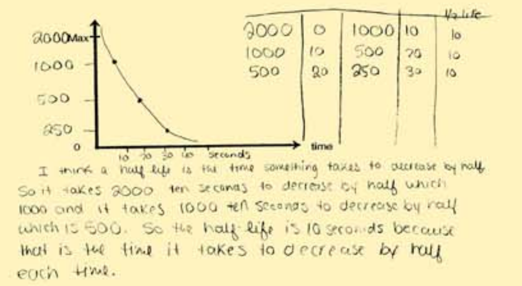
1. The dice are random.
2. Each die has a 1/6 chance per roll of landing on 1.
3. When a die lands on 1, it "emits" and is out of the game.
4. With a large number of dice, random variations average out.

Class data from 1275 dice

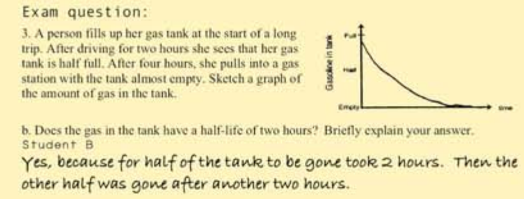


Ideas about half-lives at end:

Repeated division (goal)
The amount of time it takes for the number of radioactive atoms to decrease by 1/2. The next time interval, the current number will decrease by half again.



Subtraction
The amount of time it takes for the number of radioactive atoms to decrease by half. The next time interval, the **other half** will go. (Implies that atoms have whole-lives).
Variation: The entire amount is gone in one half-life.



Radiation (and atoms) are continuous
Half-life is the amount of time it takes for **a single radioactive atom** to release half of its radiation.

"If it has a half life at first only half of the atom is emitted into radioactivity and the other half is left until half of that is emitted and so on until nothing is left."

"I learned an easier definition of half life than what I found on the internet, it simply means that the atom decreases by 1/2 each time."

Confounding rate of radiation with time
Half-life is the **amount of atoms** emitted in a certain period of time.

"From what I understand, a half-life is the amount of time it takes for the number of atoms left in play to decrease by half. I think it's the amount of radiation that gets emitted from the atoms every minute. I'm not exactly sure I guess."

Accomplishments!

- All students were more able to assess news and current events relating to radiation.
- Students clearly distinguished EM from α, β, γ.
- Most reached "repeated division" idea of half-life.
- Some students could explain half-life behavior in terms of rules applied to nuclear processes.
- All students saw that a large number of random events can produce a predictable pattern in the aggregate.
- Students distinguished between radiation damage and contamination.
- Students appreciated learning this topic.

"What shocked me was how low the radiation count was from the microwave. You're always told don't stand too close to the screen when the microwave is on because of the radiation."

"We used . . dice games to test the half-life theory. I was suspicious of this theory at first because it didn't seem random enough. However, by rolling the dice, recording the data, and listening to Prof. Johnson, we found out that half-lives do exist. . ."

"I'm personally excited to understand that randomly discharged radiation can result in a pattern of the half-life."

"I really enjoyed learning about half-lives. It is just amazing how long some of these different radioactive materials take to get rid of their radiation. It is almost enough to make a guy nervous about what we do with all of our nuclear waste and how it affects us.."

Difficulties:

- The word "decay" implies gradual disappearance rather than discrete events. It impedes a microscopic view.
- Students thought atoms disappear when they decay.
- Students still say radiation is "waves" without saying what this means. Use of Geiger counters and cloud chamber does not spontaneously eliminate the "continuous" and "waves" ideas.
- Chemistry difficulties: Students have poorly developed models of atoms, do not connect electrons with bonding, do not distinguish between electronic and nuclear effects. Therefore, emission processes are hard to teach & not useful to most students.

"I always thought radiation was similar to light in that it went in all directions from its source in an orderly and predictable fashion. So I wondered why the monitor made blips. Now I have learned, much to my surprise, that radiation is inconsistent and random."

"I think that each nucleus keeps getting divided and that's why the radiation decreases but never goes away."

"I have learned radiation is all around us. So far it seems as if it comes in waves. There are rays of radiation that come in waves and frequencies.."

"I sucked at chemistry and it's really showing, I don't understand why if one atom were to break off or what we are supposed to get. So in conclusion I'm lost and I need everything written out in crayon."

For the future:

- Identify the origin & utility of the "waves" idea.
- Reduce to content that can be addressed by inquiry.
- May need to teach modeling to connect dice game to Ba-137 data.
- Inquiry format is possible in radiation, but development and new tools (simulations?) are needed.