Ri Christmas Lectures® 2012: The Modern Alchemist

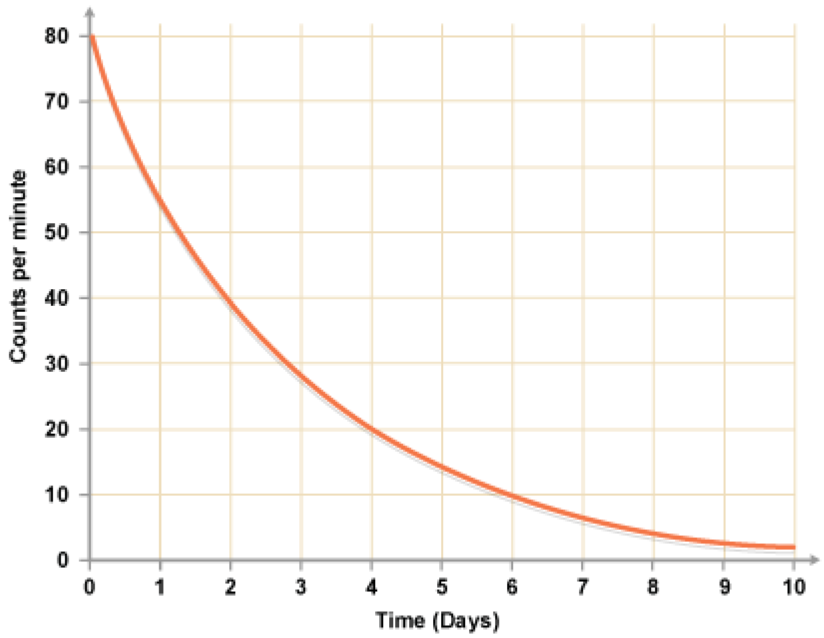
Teaching Resource - Radioactivity

Overview:

This resource contains ideas and materials to aid teachers/group leaders in the teaching and exploration of the topic of Radioactivity - in particular, how the decay of elements causes one to become another. Included are potential questions, ideas for discussion, links to video clips from the 2012 Christmas Lectures®, and suggestions of other resources which may prove useful.

What is Radiation and Radioactivity?

- Radiation can be defined as *'the emission and propagation of energy in the form of rays, waves, or particles'* - Therefore light, heat, and in fact, any type of electromagnetic wave can be classed as radiation.
- Radiation can be broadly split into two types, depending on its energy & ability to cause harm to biological systems; these being Ionising, and Non-Ionising radiation.
    - Non-ionising radiation is that which does not have sufficient energy to ionise an atom - e.g. Visible light, Radio waves, Heat.
    - Ionising radiation is that which has sufficient energy to ionise an atom - e.g. X-rays, Gamma rays, Alpha and Beta particles.
- Radioactivity can be defined as *'the act of emitting radiation'* - the form of which we are most familiar with is 'Radioactive Decay'.
    - Radioactive Decay is the process by which an unstable nuclei can move to a lower energy (become more stable) by emitting radiation - this is what most people are thinking of (even if they don't know it) when they talk about radiation.
    - Half-Life is an important term when considering radioactive decay; it refers to the time taken for half of the nuclei in a given sample to undergo radioactive decay. Some elements have a very long half life (Uranium-238, around 4.47 billion years) while some are very short (Francium-223, 22 minutes).
    - An example of a graph of radioactive decay is shown below; from this graph we can calculate the half life of the material. Initially, the material shown 80 counts per minute, and the time taken fr this to reduce to 40 counts per minute is 2 days. Therefore, the half-life is 2 days. So, the time taken for the counts per minute to reduce from 40 to 20 is also two days, and so on.



- Ideas for discussion:
    - What is radiation?
    - Where do we use radiation in our lives?
        - Caesium in atomic clocks (See US National Physical Laboratory[1])
        - Microwave ovens
        - Medicine (a large area, potentially a research project, See Medical Uses[2])
        - Nuclear Power (Nuclear Industry Association[3])
    - Where does radiation come from; is it man made, or natural?
        - Both... 80 % of a persons average yearly dose is natural, while around 20 % is related to man made activities (of which medical exposure makes up > 98 %)
        - The average person receives a dose of 3.01 millisieverts a year (the fatal dose of radiation is around 4 sieverts; a sievert is equivalent to one joule of energy per kg of mass. See the Encyclopaedia Britannica[4])

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[1] National Physics Laboratory, http://www.npl.co.uk/educate-explore/what-is-time/
[2] International Atomic Energy Agency, http://www.iaea.org/Publications/Booklets/RadPeopleEnv/medical.html
[3] Nuclear Industry Association, http://www.niauk.org/educational-booklets
[4] Encyclopaedia Britannica, http://www.britannica.com/EBchecked/topic/543504/sievert-Sv

Video Clip - Radioactivity and the Nucleus:

In this clip from the 2012 Christmas Lectures®, Dr Peter Wothers explains the process of radioactive decay to show how one element can become another through loss of part of its nucleus.

Radioactivity

Running Time: 2 min 48 secs

Types of Radioactive Decay:

Several different forms of ionising radiation are commonly released by radioactive decay:

- α- (alpha-) particle
  - An alpha particle is in effect a helium-4 nucleus, consisting of two protons and two neutrons. It is a relatively slow moving (typically with a velocity of ~ 5 % of the speed of light), heavy particle, and as such can be stopped by a sheet of paper.
  - Loss of an alpha particle from a nucleus reduces the number of protons within the nucleus by two; thus transmuting the nucleus into a different, lighter, element.
- β- (beta-) particle
  - A beta particle is simply a high speed, high energy electron. Beta particles have a greater ability to penetrate matter than alpha particles, but typically can be stopped by a few millimetres of aluminium. Beta particles are also more strongly ionising than gamma rays.
  - For advanced consideration, there are two types of beta particle, b^- and b^+; b^- are electrons, while b^+ are the corresponding antiparticle, i.e. a positron.
- γ- (gamma-) ray
  - Not a particle, gamma rays are very high energy electromagnetic waves. They are typically of much higher energy than both alpha and beta particles, and have much greater ability to penetrate matter. This ability means that high density materials (such as lead) are required to shield against them.

Video Clip - Cloud Chamber

In this clip behind-the-scenes at the 2012 Christmas Lectures®, Dr Peter Wothers demonstrates how a cloud chamber can be used to visualise background radiation - and discusses the characteristic signs shown by the release of alpha and beta particles.

The Cloud Chamber

Running Time: 2 min 40 secs

Class Activity/Workshop: Building a Cloud Chamber

A video on how to build a simple cloud chamber can be found here[5].

Further information about radiation, its uses, effects, and dangers can be found in the following resources:

- International Atomic Energy Agency (www.iaea.org, or Radiation, People, and the Environment[6])
- Health Protection Agency (www.hpa.org.uk, or Understanding Radiation[7])

View the full 2012 Ri Christmas Lectures® - The Modern Alchemist, along with behind the scenes footage, and related content, at the Ri Channel[8].

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[5] How to make a cloud chamber, Youtube, http://www.youtube.com/watch?feature=player_embedded&v=400xfGmSlqQ
[6] International Atomic Energy Agency, http://www.iaea.org/Publications/Booklets/RadPeopleEnv/index.html
[7] Public Health England, http://www.hpa.org.uk/Topics/Radiation/UnderstandingRadiation/
[8] The Ri Channel, www.richannel.org