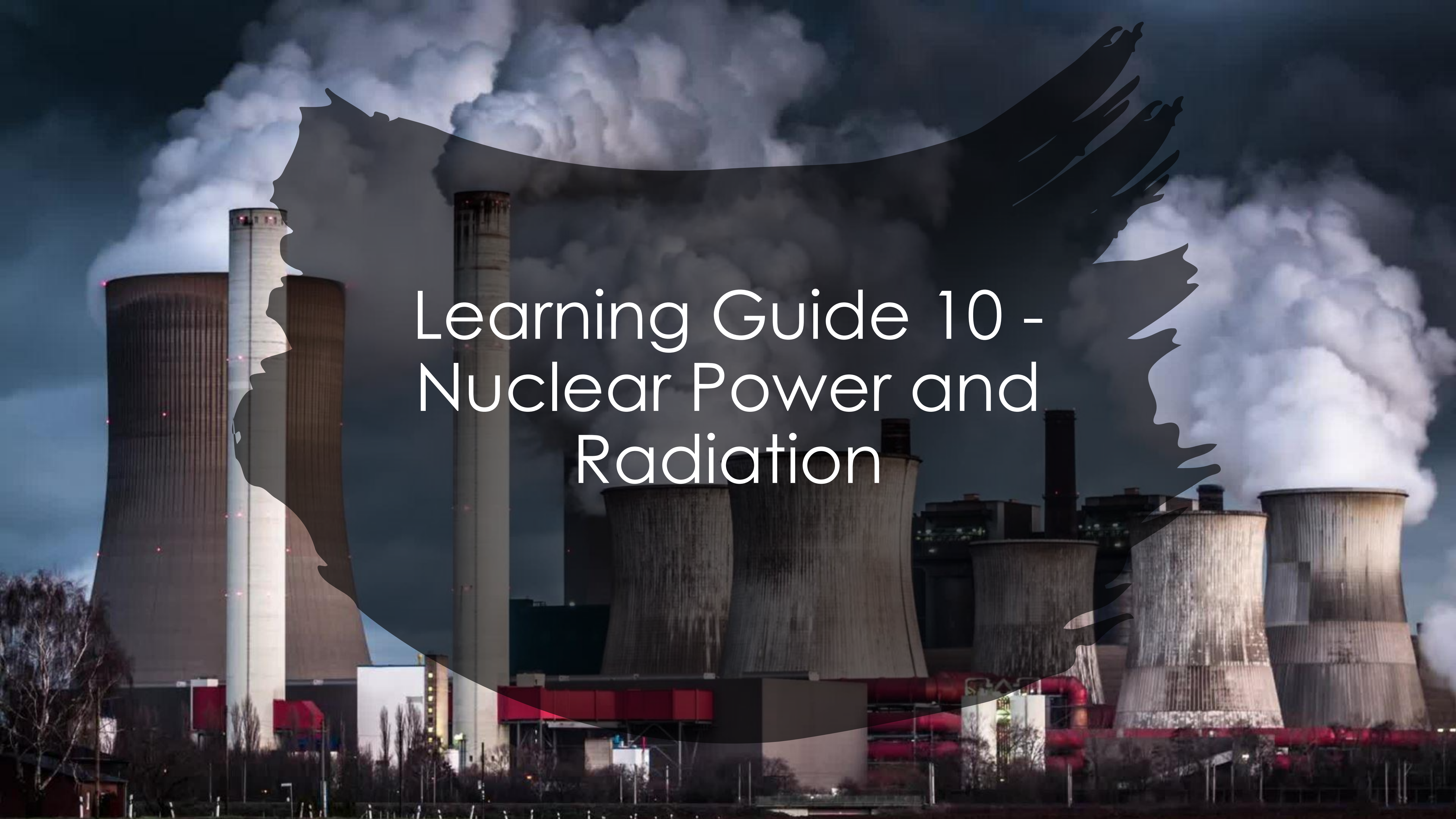
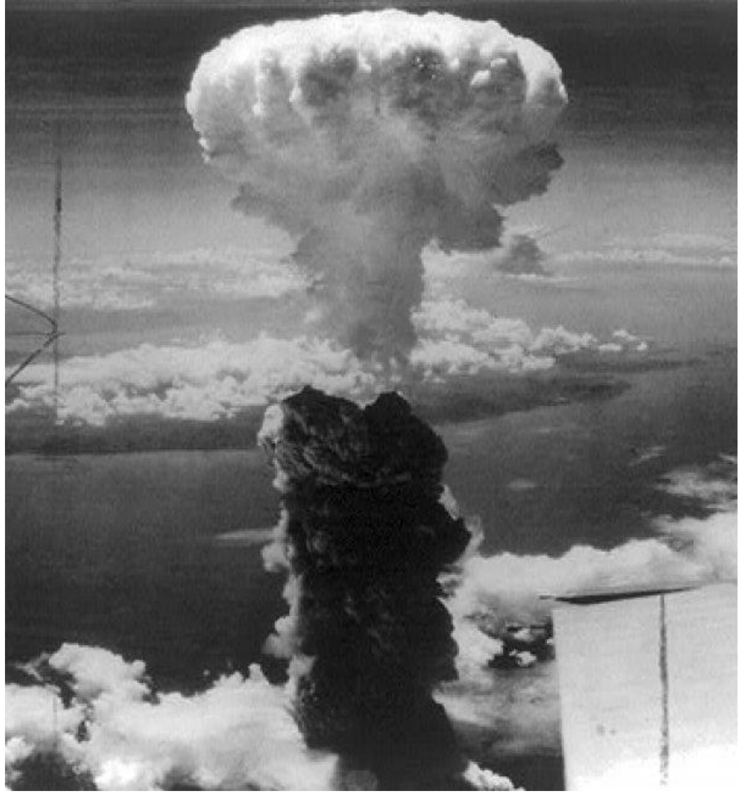
Learning Guide 10 - Nuclear Power and Radiation

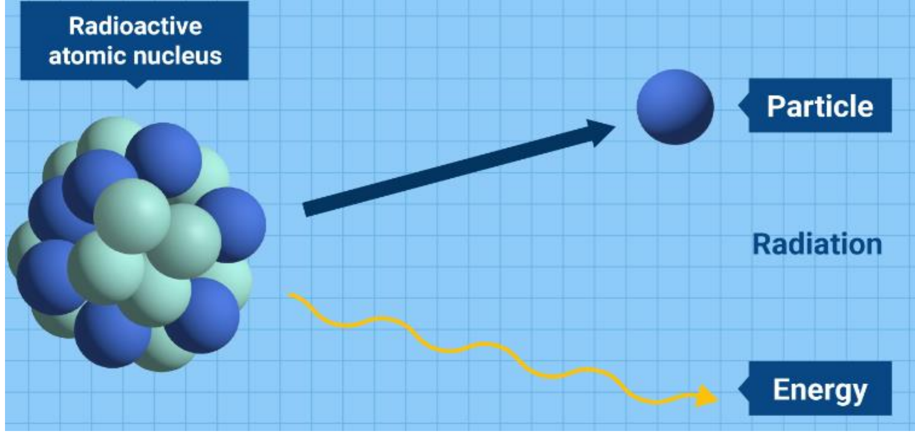


Nuclear Energy

- Nuclear energy is energy that is stored inside the nucleus of atoms and is released in two processes called nucleus fission and nuclear fusion.
- Recall that the nucleus is made up of protons and neutrons. These are the subatomic particles that are used to store the nuclear energy, not the electrons.

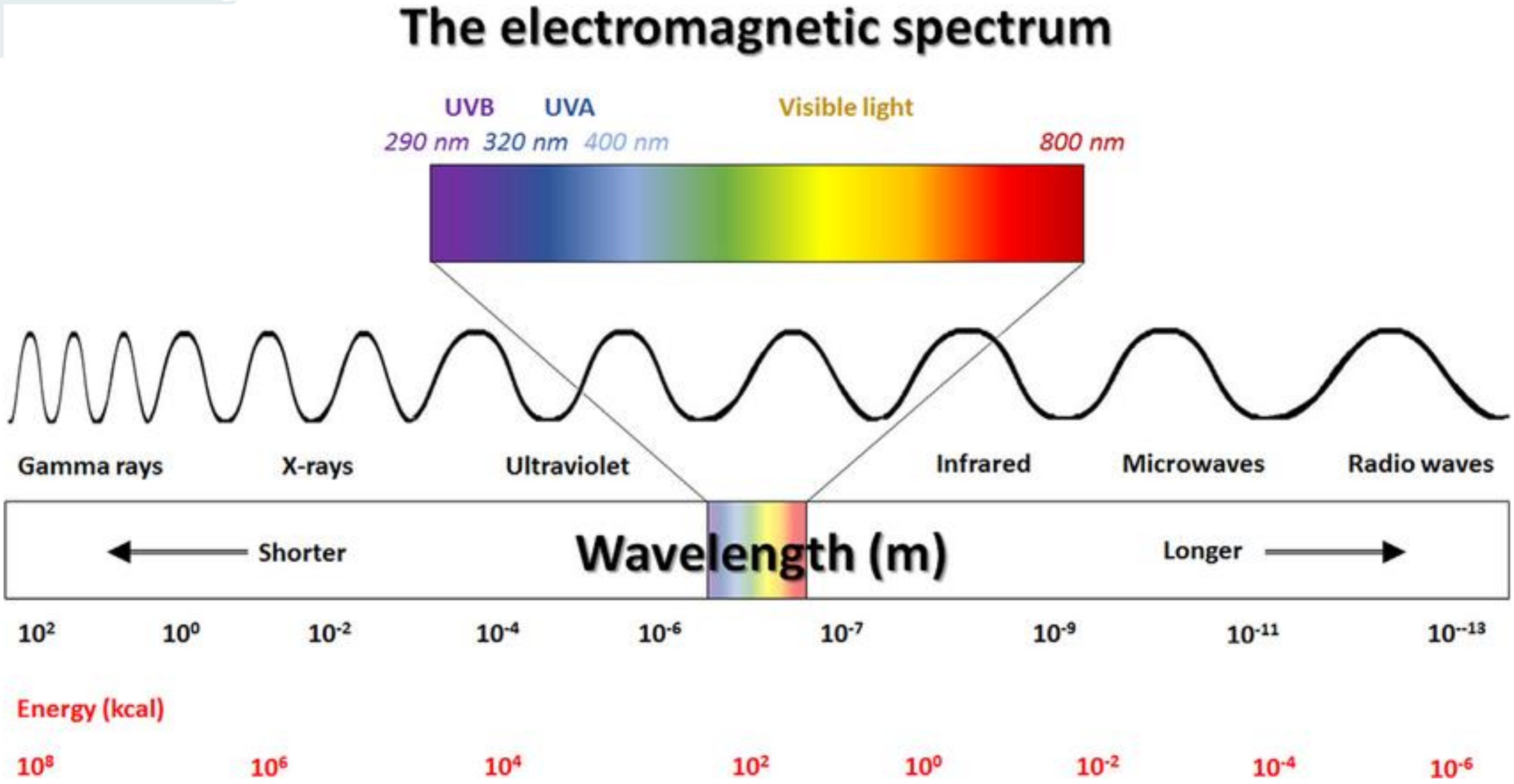


Radiation



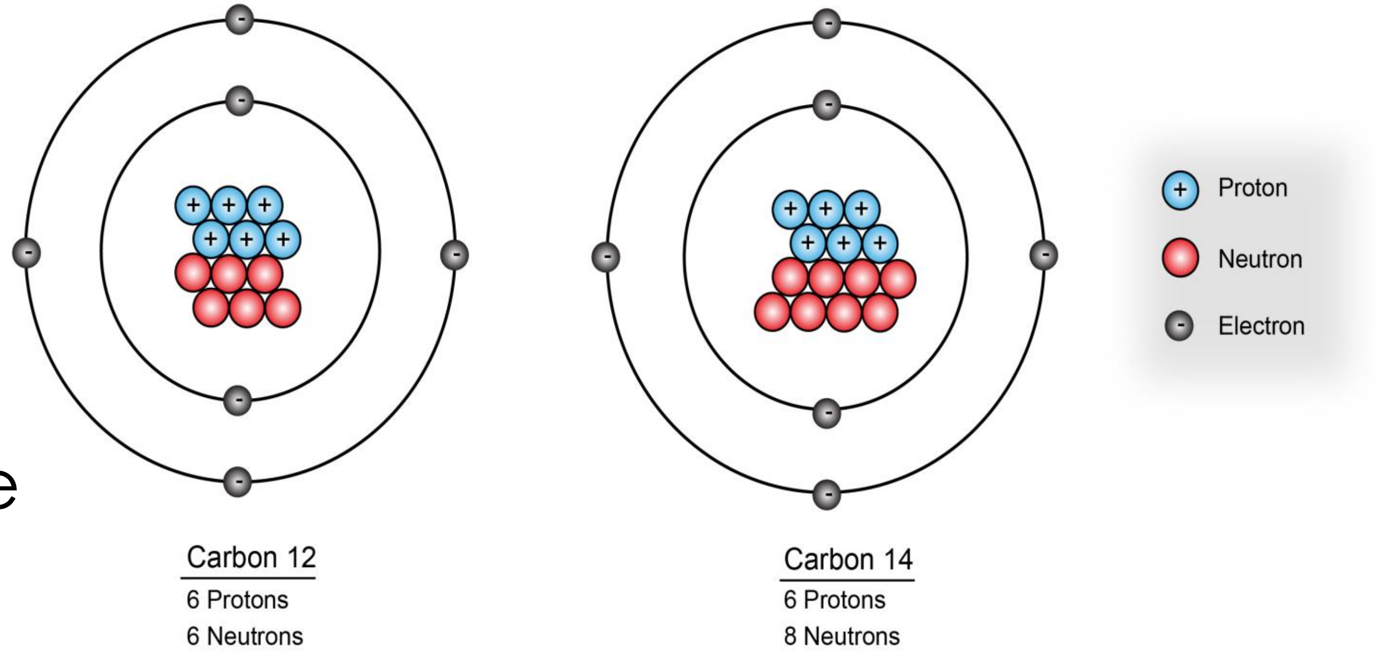
- When changes are made to the nucleus, high energy particles/waves can be released. This is called radioactivity (the ability to release these high-energy particles).
- There are different types of radiation, which we have seen in grade 8 in the electromagnetic spectrum. Radio Waves, Microwaves, Inferred Radiation, Visible Light, Ultraviolet, X-rays, Gamma Rays, and Comic Rays

Its Back!


The electromagnetic spectrum
UVB
UVA
Visible light
290 nm
320 nm
400 nm
800 nm
Gamma rays
X-rays
Ultraviolet
Infrared
Microwaves
Radio waves
Shorter
Wavelength (m)
Longer
10^2
10^0
10^-2
10^-4
10^-6
10^-7
10^-9
10^-11
10^--13
Energy (kcal)
10^8
10^6
10^4
10^2
10^0
10^-2
10^-4
10^-6

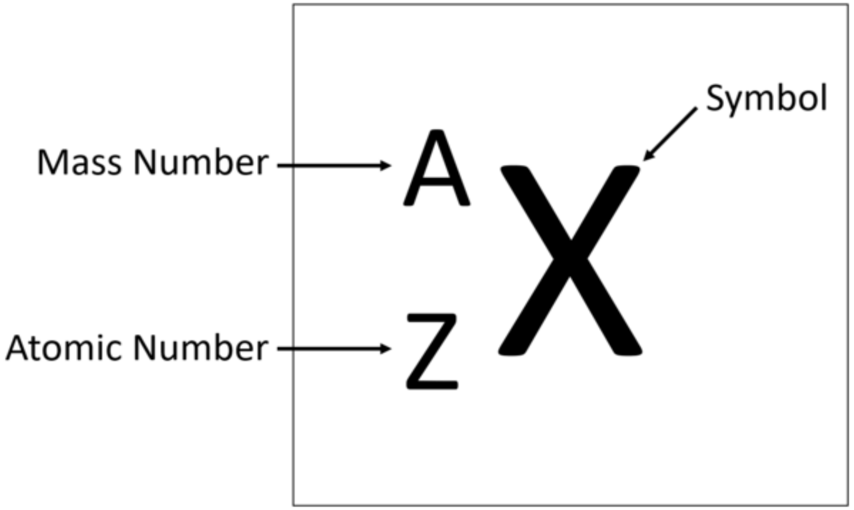
Isotopes

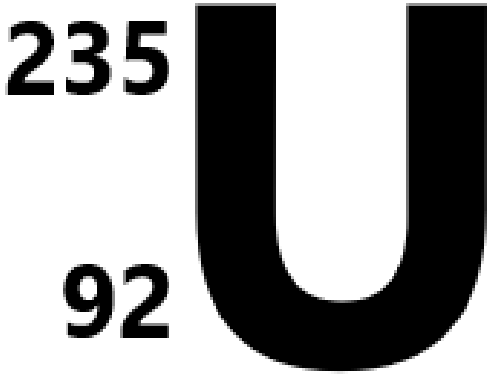
- If we look at the periodic table, we notice that the atomic masses are decimals. However, we know that the atomic mass is the protons + neutrons, and you cannot have a piece of a proton or neutron normally.
- We use decimals because there are many versions of each element, called Isotopes, with different numbers of neutrons. The atomic number is an average of the versions, leading to a decimal.



Standard Atomic Notation

- Standard Atomic Notation is used as an easy way to note down which isotope of an element we are using.
- The mass number is always on the top and will be the protons and neutrons added together. This can change without changing the element.
- The atomic number is always on the bottom. It is aways the atomic number of the element noted by the symbol.
- As a word, an isotope can be state by the element name, followed by the atomic mass.





Uranium - 235 Standard Atomic Notation

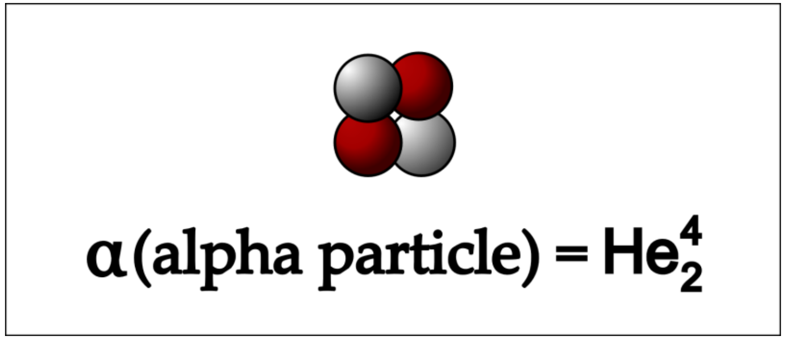
Atomic Stability and Decay

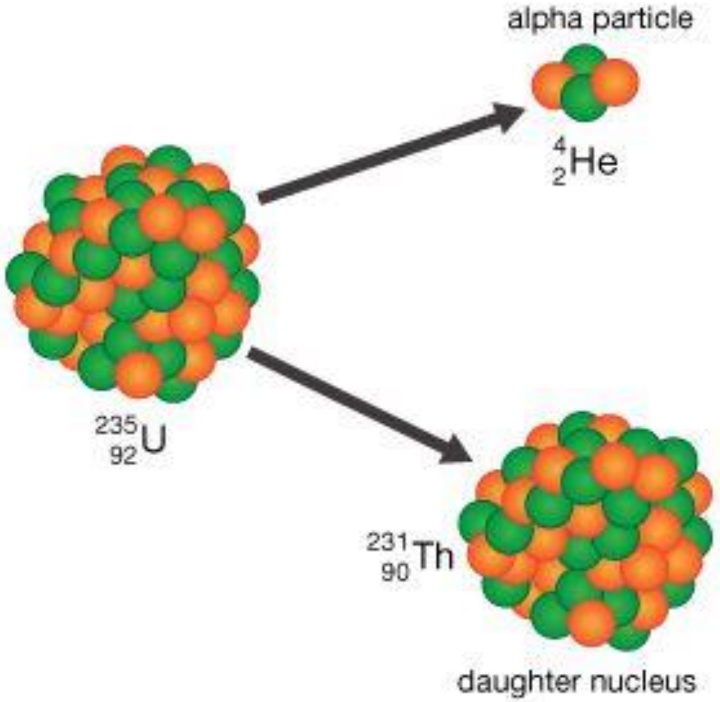
- Each element isotope has a specific stability.
- When isotopes are less stable, they can undergo radioactive decay, releasing particles and energy to reach a more stable form.
- Elements can decay away and turn into other elements. Example: Potassium can decay into Argon (after billions of years)
- Radioisotopes are isotopes made in a lab or in nature that can decay into other elements

$$^{40}_{19}K \rightarrow ^{40}_{18}Ar$$

3 Main Types of Decay - Alpha

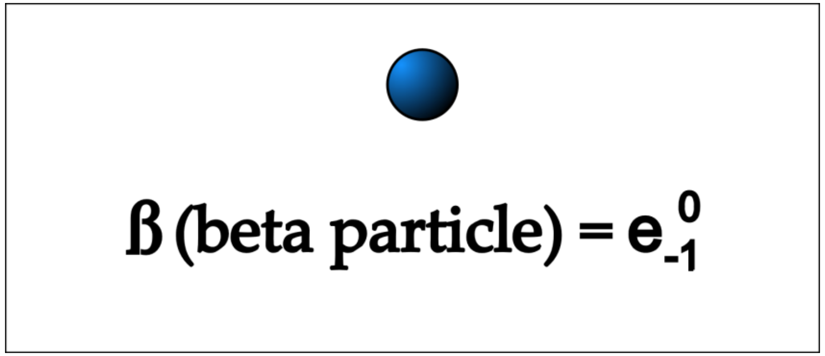
- There are three main types of decay that are dependent on the type of particle they emit.
- When decay occurs, the isotope you begin with is called the parent isotope, and the isotope you end with is called the daughter isotope.
- There is always a particle or wave emitted. For alpha radiation, an alpha particle is emitted that has an atomic mass of 4 and 2 protons.
- Because element number 2 is helium, we often call this particle a helium particle.

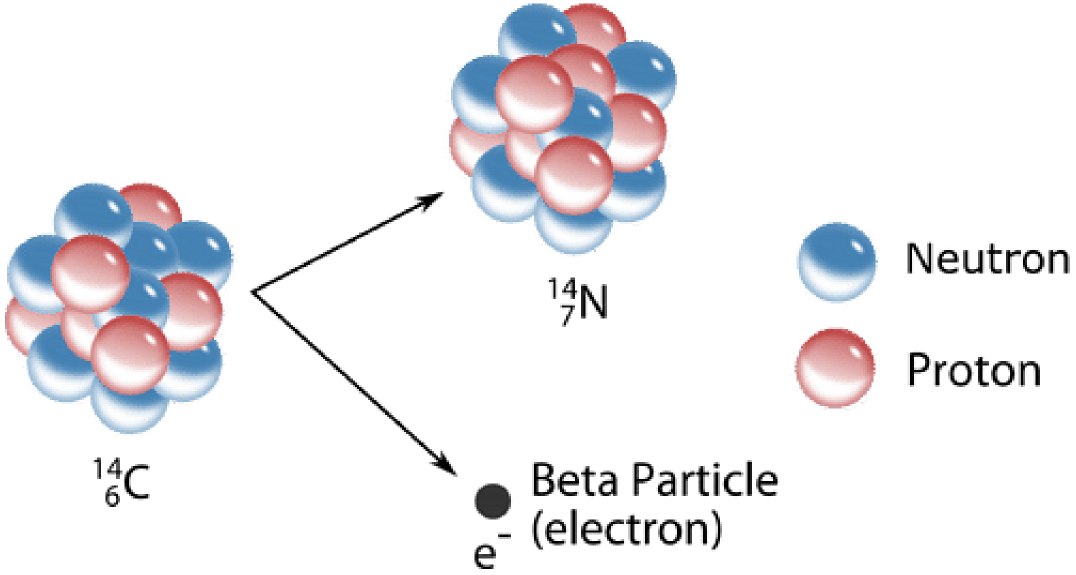




3 Main Types of Decay - Beta

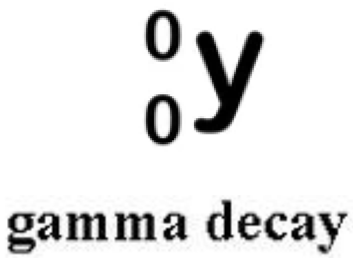
- Beta particles are particles that emit a particle with a mass number of 0, but an atomic number of –1.
- -1 as an atomic number is kind of like the opposite of a proton, which is an electron, so the emitted beta particles are often referred to as electrons.
- This results in the daughter isotope becoming bigger than the parent isotope.
- Side note: this decay is more complex, so if you do research, know that is can emit other foundational particles like neutrinos and positrons.

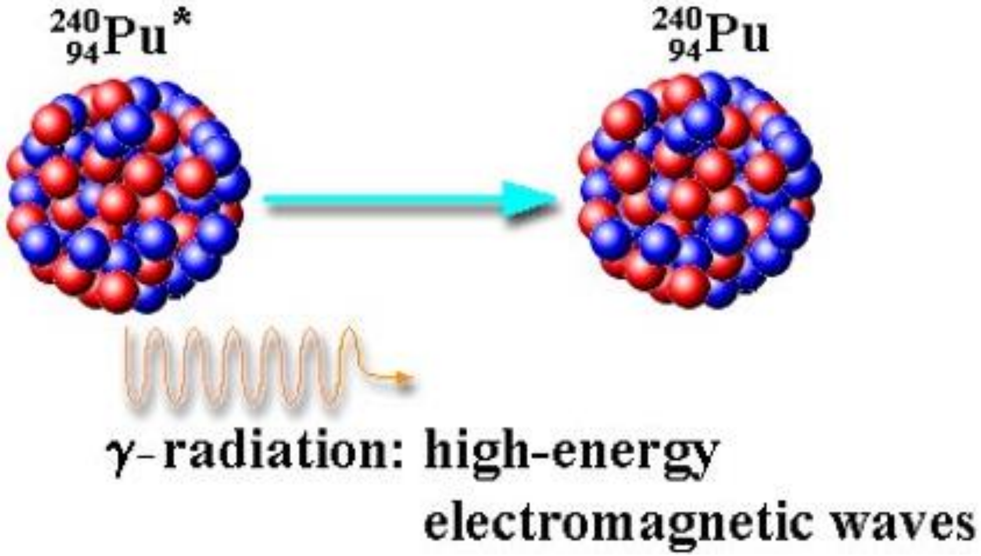




3 Main Types of Decay - Gamma

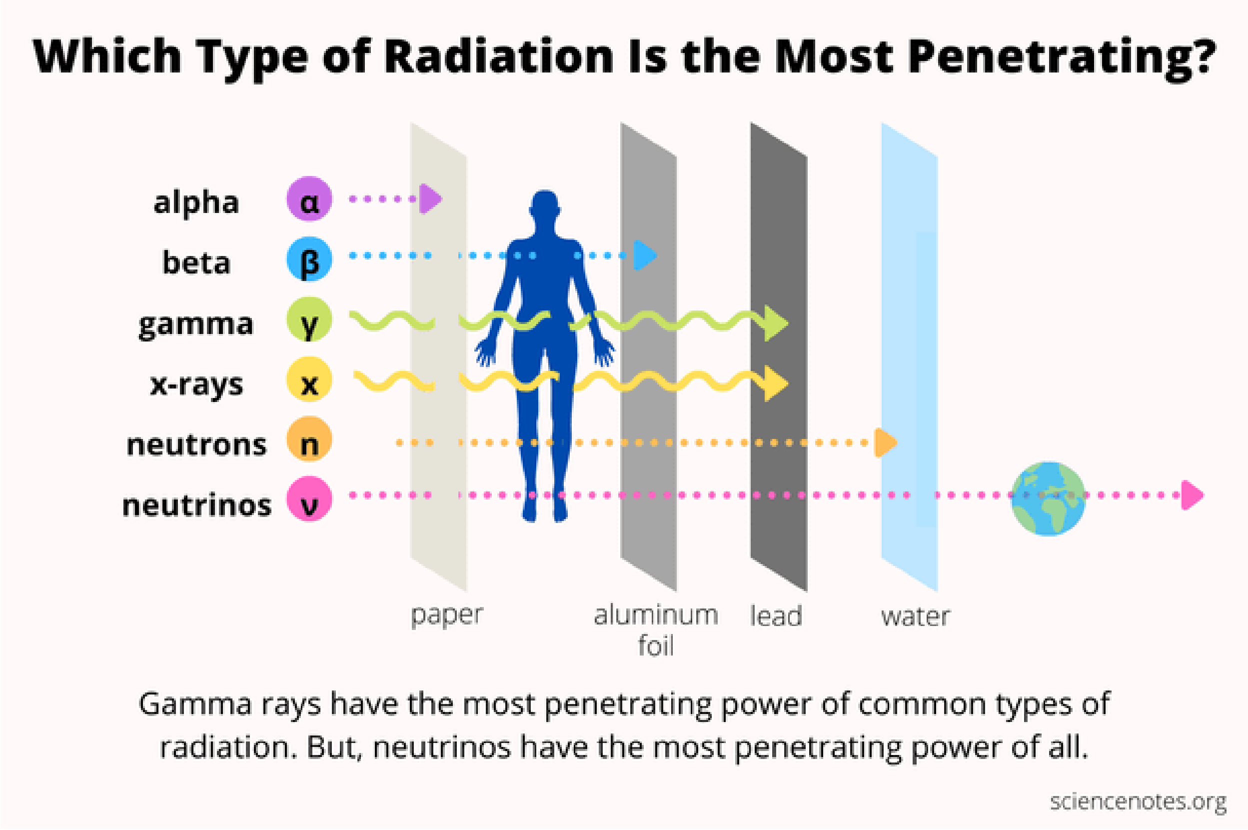
- When a charged ion captures an electron, the nucleus can enter a charged-up state, becoming known as an excited nucleus.
- We often note an excited isotope with a small asterisk.
- After a while of being in this excited state, the extra energy can be lost in the form of gamma radiation.
- A gamma ray has no protons, neutrons, or electrons, so none of the numbers or elements change, the asterisk just goes away.





3 Main Types of Decay - Alpha

- The three particles have different levels of energy and have different abilities to pass through objects.
  - The alpha particles are the weakest and cannot even pass through paper.
  - The beta particles can through paper and humans, but not things like aluminum foil.
  - Gamma rays can pass through most objects except lead and similar materials. X-rays in modern technology are similar to gamma rays, but not the same.
  - Ignore the other two foundational particles for this course.



Using Math/Chemistry Equations in Decay

- We can use our chemistry equations and some basic (calculator allowed) math in order to find missing information in questions.

$$ {}^{20}_{9}\mathrm{F} \dashrightarrow {}^{20}_{10}\mathrm{Ne} + \underline{\qquad\qquad} $$

In this example, we can see that if the right side of the equation loses 1 on the bottom numbers (protons), then it will match Fluorine.

This means the blank must be an electron (with –1 on the bottom), meaning this is beta decay.

Using Math/Chemistry Equations in Decay

$$^{214}_{83}\text{Bi} \dashrightarrow {}^{210}_{81}\text{Tl} + \underline{\qquad\qquad}$$

In this example, the left side is 4 bigger on the top and 2 bigger on the bottom.

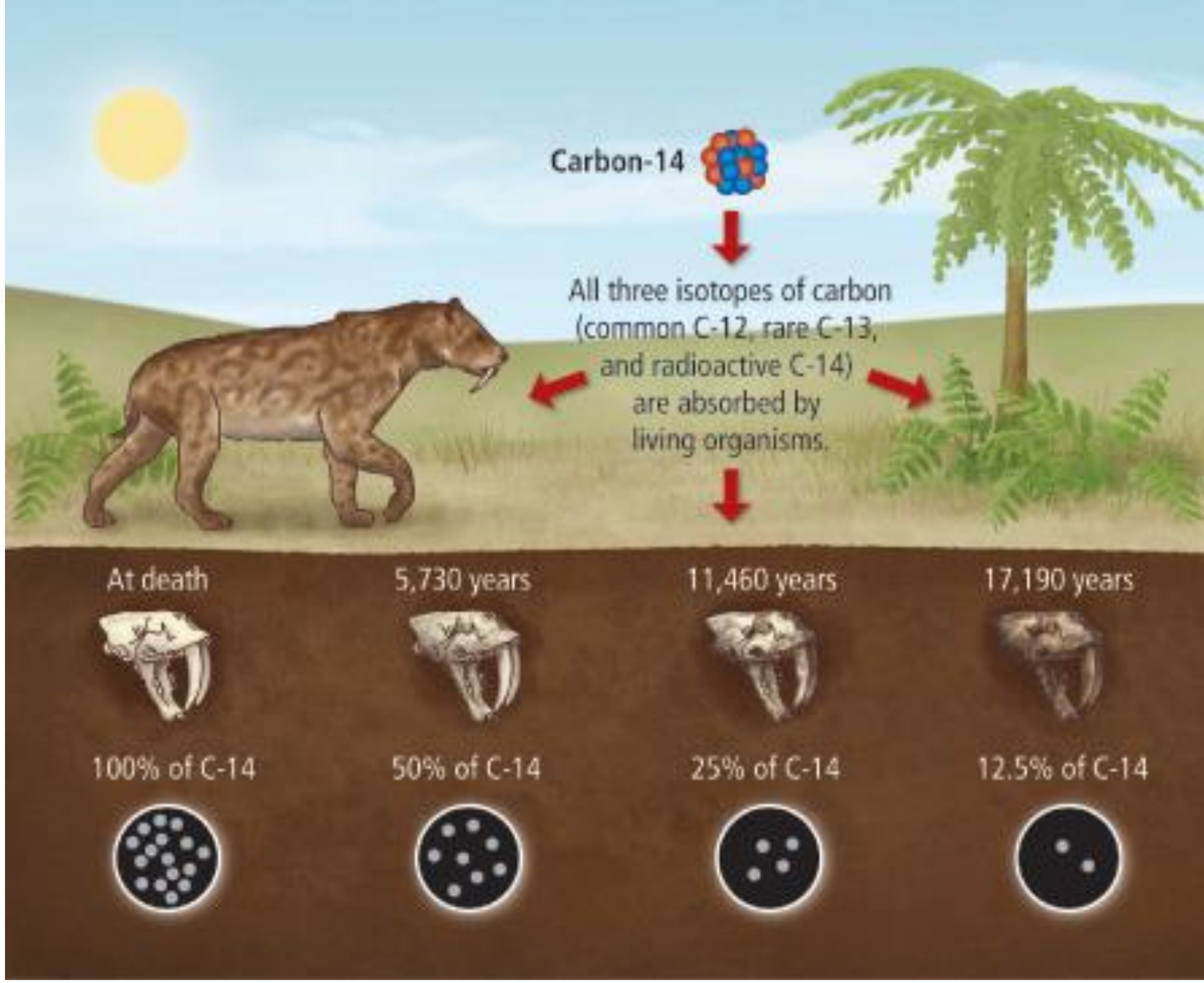
This means the blank must be an alpha particle to balance out both the top numbers and bottom numbers.

$$^{58}_{26}\text{Fe*} \dashrightarrow {}^{58}_{26}\text{Fe} + \underline{\qquad\qquad}$$

Hey look! There is an asterisk and none of the numbers change. This is gamma decay.

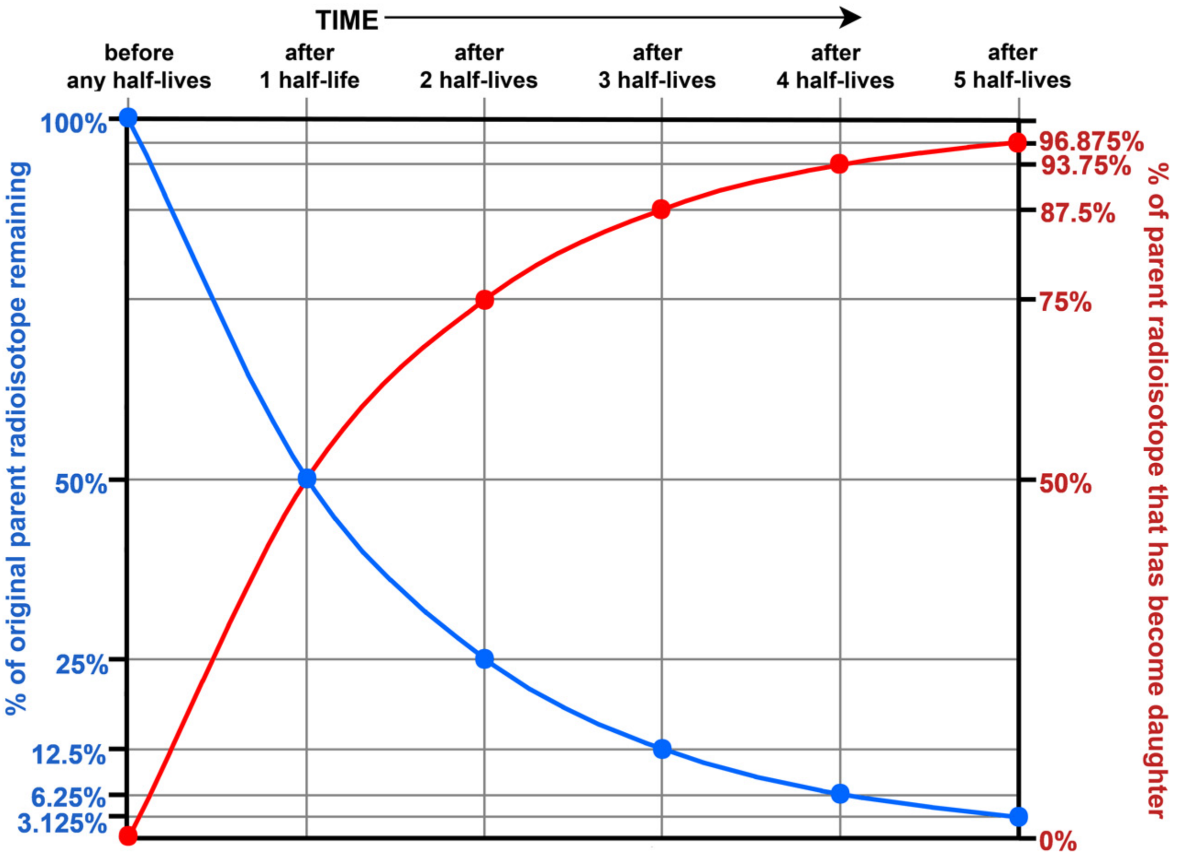
Half-Life

- Half-Life is a period of time in which half a sample decays into something else.
- The time of a half-life varies depending on the parent isotope.
  - If the parent is unstable, it can be less than a second.
  - If the parent is more stable, like potassium-40, its half-life can be 1.3 billion years.
- Half-life be used to see how old something is, like a potassium clock for Earth, or carbon dating for fossils.



Half-Life Graphs

- Graphs can be made to model hoe much of a parent isotope is left and how much a daughter isotope has formed based on the number of half-lives that have occurred.
- Please note that yes, you can have fractions of a half-life, as the material is continuously decaying.
- In the graph, we can see that whenever the parent isotope loses a percentage of itself, we can see the daughter isotope has gained the amount.
- Another thing to note is that the graph **will never hit zero percent in theory.**

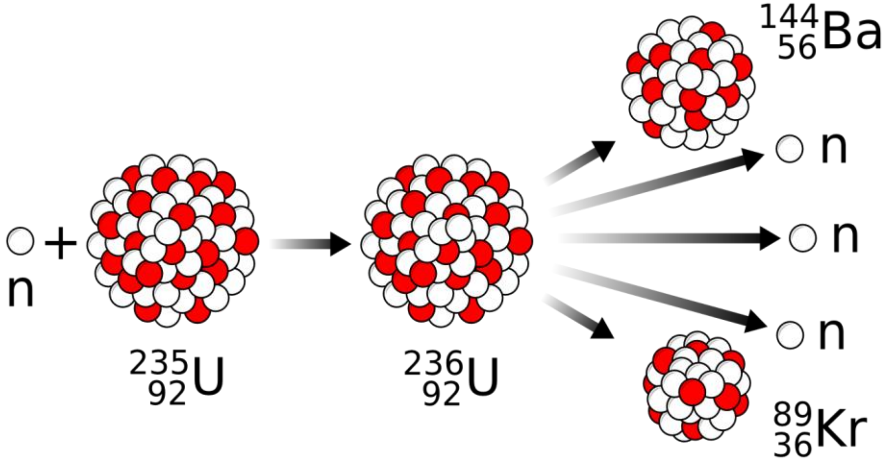


Nuclear Reactions

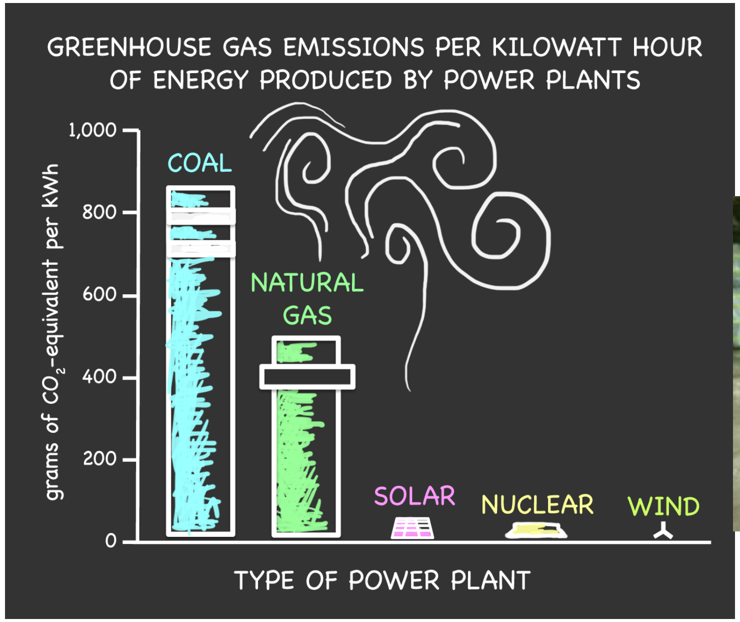
- There are two types of nuclear reactions that produce amazing amounts of energy: Nuclear fusion and Nuclear Fission.
- **Nuclear <u>Fission</u>** is when a parent isotope splits (typically due to being hit by alpha/beta particle or gamma ray) and results in two, smaller daughter isotopes.
- **Nuclear <u>Fusion</u>** is when 2 parent isotopes are combined to form 1, larger daughter isotope.

Nuclear Fission

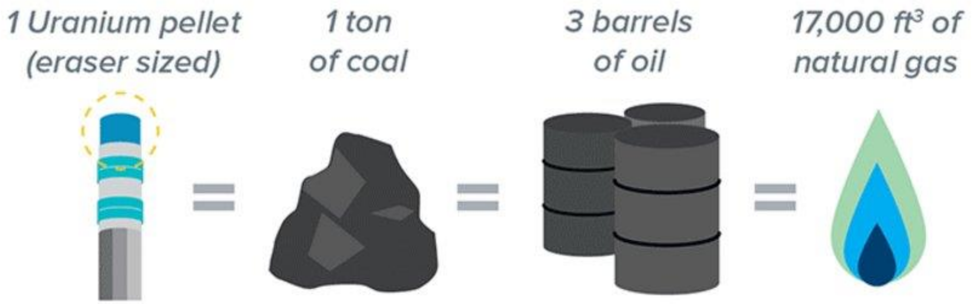
- Below, a particle (neutron) hits a Uranium isotope, splitting it into Barium and Krypton isotopes. This also releases 3 more neutrons and a lot of energy.



$${}^{1}_{0}n + {}^{235}_{92}U \longrightarrow {}^{92}_{36}Kr + {}^{141}_{56}Ba + 3\,{}^{1}_{0}n + \text{energy}$$

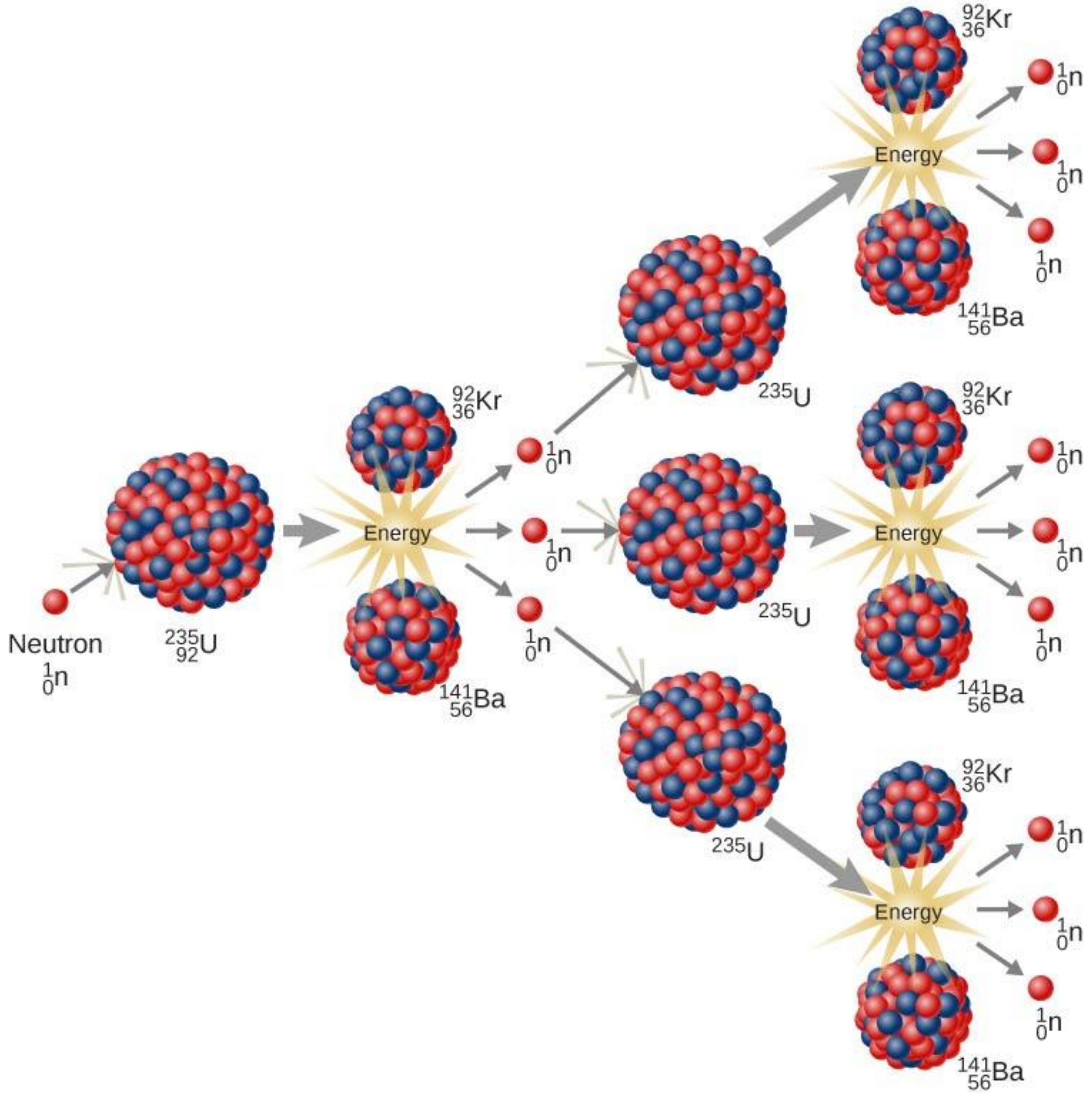


- Nuclear fission can be caused by humans (or nature) to release large amounts of energy in powerplants, weapons, and more.
- Downside: leaves hazardous radioactive nuclear waste for thousands of years.



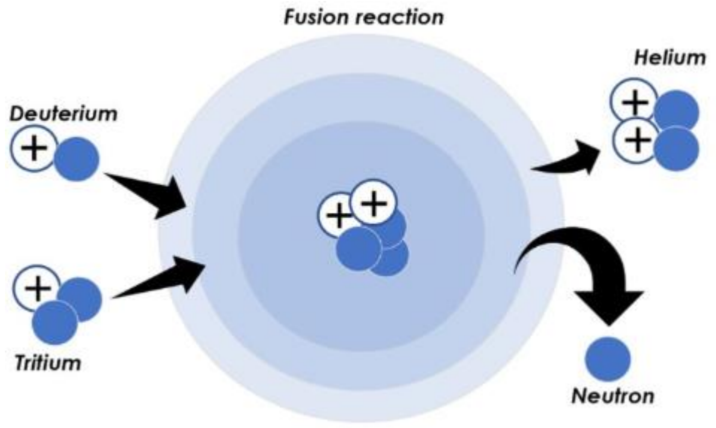
Chain Reaction

- Chain reactions occur when the particles emitted from the first reaction hit particles around them, leading to more reactions. This pattern continues until most of the material is reacted.
- Because our example emits 3 more neutrons, our reactions gets 3x more particles to react after each reaction. This follows a 3^x pattern.

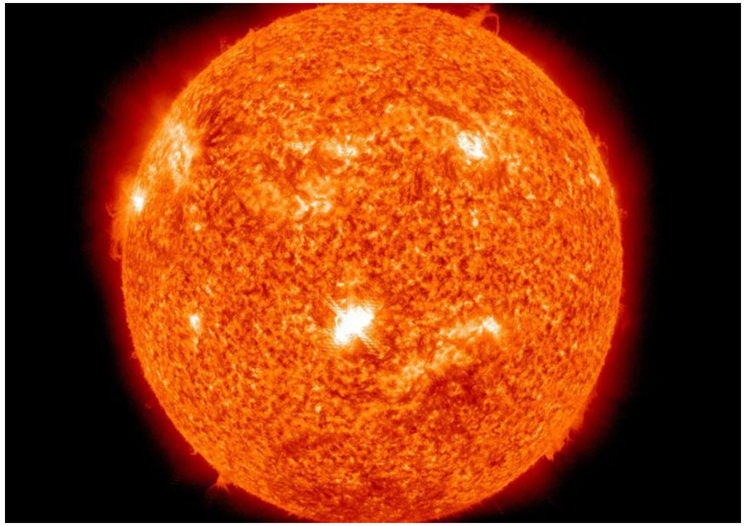


Nuclear Fusion

- Below, 2 hydrogen isotopes combine under massive pressure and temperature to create helium and a large amount of energy (and another neutron for chain reactions.



$$^{2}_{1}H + ^{3}_{1}H \longrightarrow ^{4}_{2}He + ^{1}_{0}n + \text{energy}$$



- Nuclear fusion is like fission, but it **does not create any nuclear radioactive waste,** as helium is stable.
- Why not use fusion? While humans have recreated small nuclear fusion, large scale nuclear fusion requires a lot of pressure and temperature. To put it into perspective, stars use nuclear fusion, and the sun has 100 billion times more pressure than air on Earth and 27 billion times hotter than Earth.
- This could be the next major technological breakthrough if possible.

Balancing a Nuclear Reaction

- Just make sure the tops numbers are equal on both sides of the chemical equation. Same for the bottom numbers.
- Keep in mind, you can use more than one particle (put a coefficient in front of the particle).

$$ {}^{1}_{0}n + {}^{235}_{92}\mathrm{U} \dashrightarrow {}^{115}_{49}\mathrm{In} + {}^{118}_{43}\mathrm{Tc} + \_\_\_\_ \; {}^{1}_{0}n $$

- In this example, we need 3 neutrons so that the tops are equal.
    - Left: 1 + 235 = 236
    - Right: 115 + 118 = 233 + 3 X 1 = 236