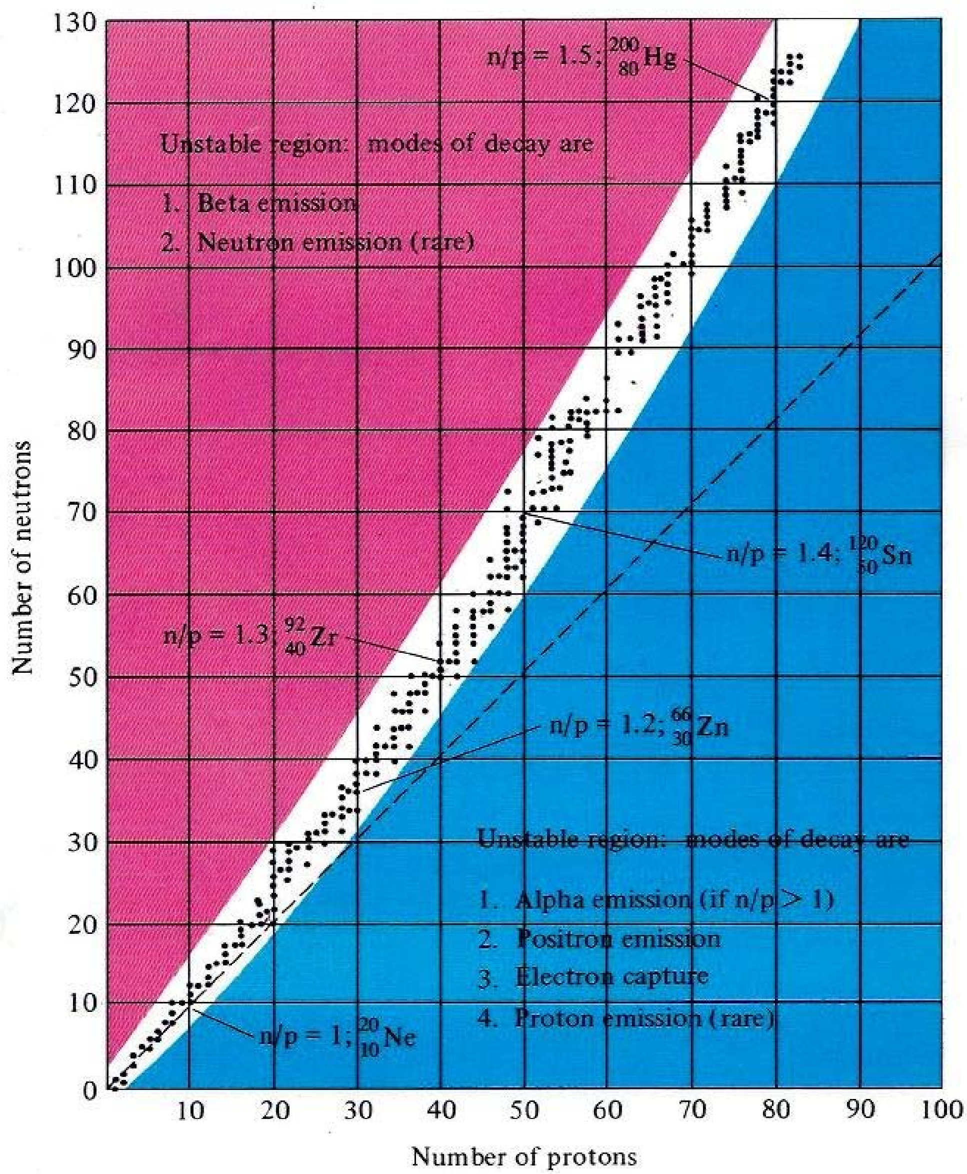
STATION 17

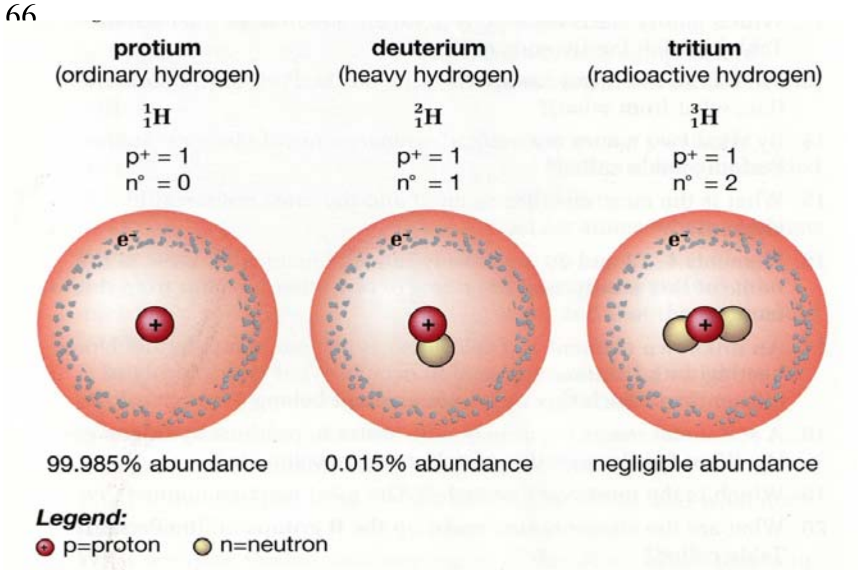
NUCLEAR STABILITY AND RADIOACTIVITY

Except for the proton to neutron ratios found for the stable nuclei such as the black dots in the white region in the chart to the right, other proton to neutron ratios are not stable. The half lives for unstable nucleii range from microseconds to trillions of years.



The decay changes the proton to neutron ratio sometimes resulting in a stable isotope and sometimes in a new radioactive nucleus.

Some stable isotopes as well as examples of radioactive isotopes of hydrogen, carbon and uranium are shown on the next page.

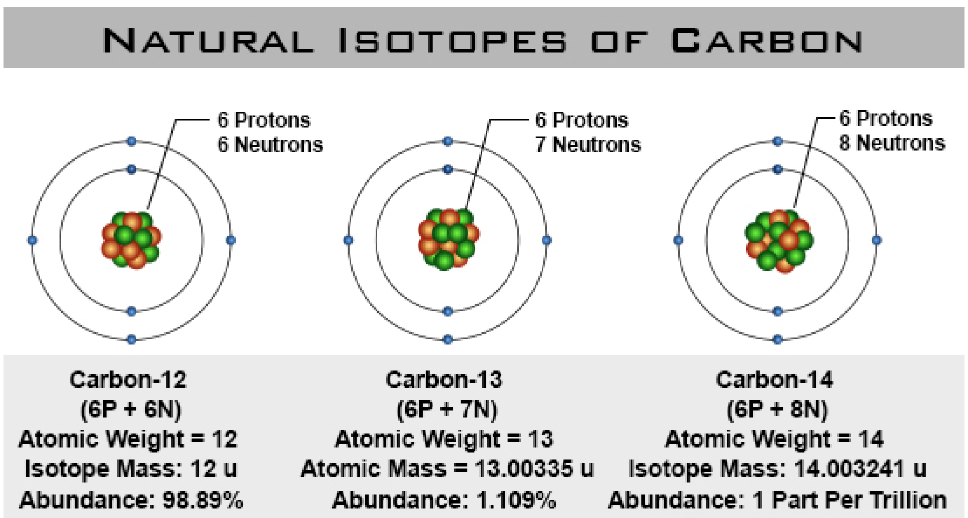


Tritium → electron + helium

^{3}H $\quad ^{0}_{-1}e \quad$ ^{3}He

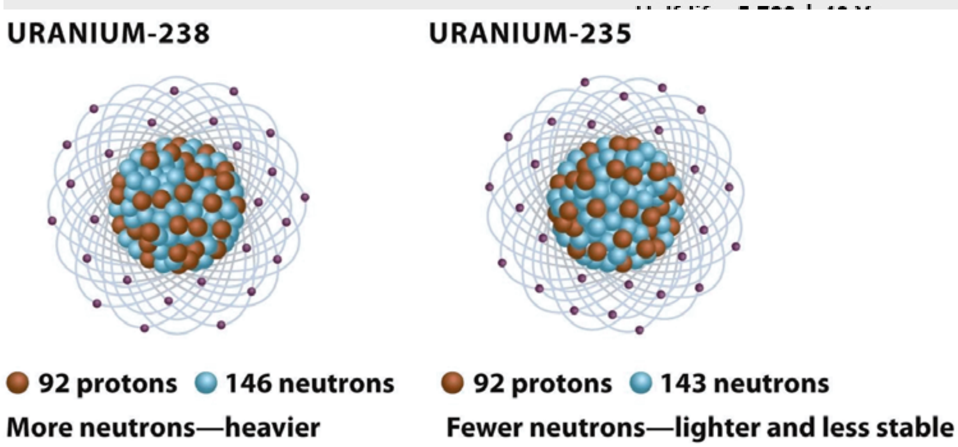
$$t_{1/2} = 12.3 \text{ years}$$

As shown, tritium decays by emitting an electron otherwise known as a β particle. It takes 12.3 years for half of the tritium present to decay.



$$^{14}_{6}C \rightarrow \, ^{14}_{7}N + \, ^{0}_{-1}\beta$$

With a half life of 5730 years, carbon-14 decays by emitting a β particle and is commonly used to date once living items up to about 60,000 years old.



$$^{238}_{92}U \rightarrow \, ^{234}_{90}Th + \, ^{4}_{2}\alpha$$

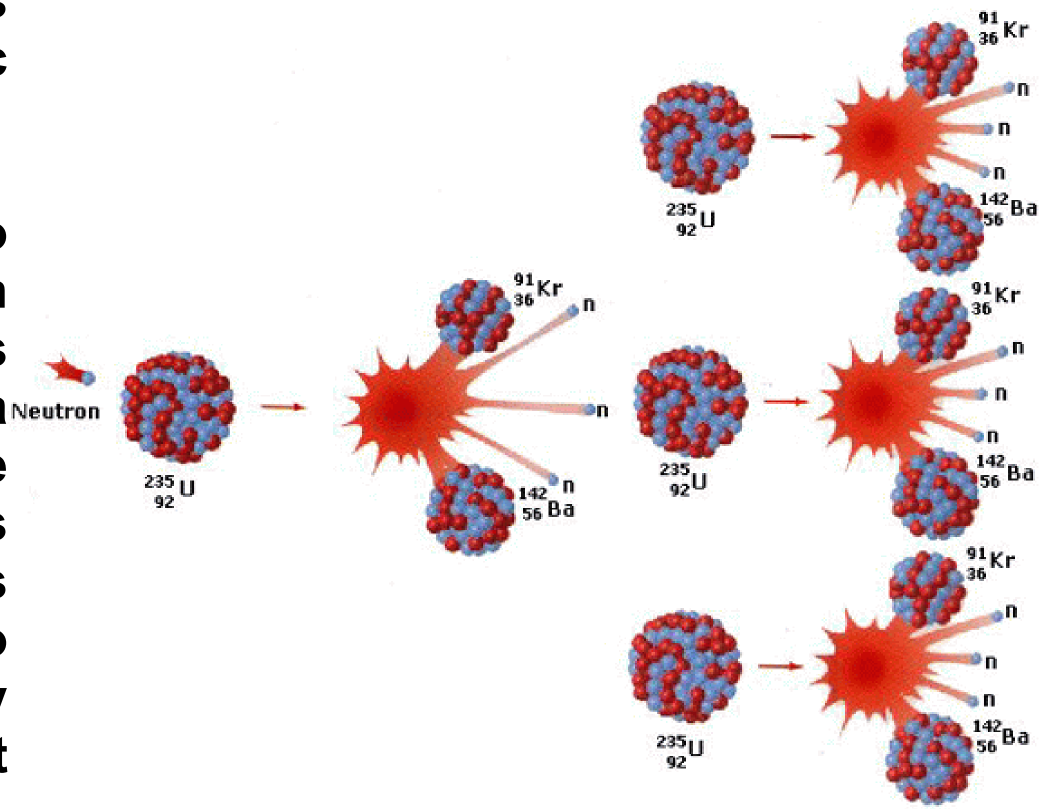
$$^{235}_{92}U \rightarrow \, ^{4}_{2}He + \, ^{231}_{90}Th$$

isotope	U-238	U-235
abundance(%)	99.3	0.7
half life (yrs)	4.5×10^{9}	7.0×10^{8}

Both of the uranium isotopes that are found on earth decay by emitting a helium nucleus otherwise known as an α particle. 99.3% of uranium ore is the isotope U-238 and U-235, the remaining 0.7%. However, of the two isotopes, only U-235 undergoes fission.

The low percentage of naturally occurring uranium-235 is a major issue for countries desiring to build either nuclear energy facilities or atomic (fission) bombs.

As shown to the right, when U-235 is impacted by a neutron, the nucleus splits (undergoes fission) with two extremely important consequences.



In addition to the formation of two small nuclei, two (sometimes three) neutrons are emitted along with a huge amount of energy (a significant amount of mass is converted to energy in the reaction). The three neutrons can impact 3 more U-235 nuclei resulting in more energy and 9 neutrons. This becomes a chain reaction and will proceed with a high rate of speed and a nuclear explosion if the neutron flux is not controlled and sufficient U-235 (critical mass) is present. If U-238 is impacted by a neutron, the neutron causes a transmutation to neptunium and does not fission. If naturally occurring uranium is impacted by neutrons, 99.3% of the time U-238 will be hit rather than fissionable U-235. Even if a U-235 is impacted , the neutrons will almost always impact a U-238 and the chain reaction does not continue.

To carry out a chain reaction, the uranium ore must be enriched to a high enough concentration of U-235 for a sustainable chain reaction. Because isotopes behave almost the same physically and chemically, separation or enrichment is time consuming and very expensive.

The controversial Iran nuclear treaty involves the issues discussed above. Iran would like to enrich uranium and they have the centrifuges needed to do this. Iran claims that they want to enrich the uranium enough to use in peaceful nuclear energy facilities. Bomb enrichment requires even higher percentages of U-235 than energy facilities require. The treaty restricts Iran to preparing the U-235 sufficient for energy facilities but insufficient for bomb use. Some people and countries do not believe that Iran will abide by the rules.

This station has several household items that will be tested for radioactivity. While exposure to radioactivity should be minimized, small amounts are not significantly harmful. The Geiger counter adjacent to the turntable will react audibly to radioactive sources with a clicking sound.

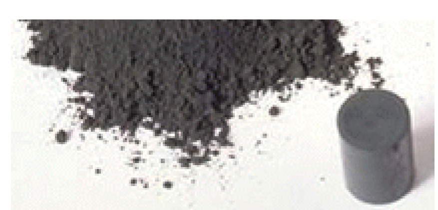
Which of the items on the turntable are radioactive?

Fiesta ware

radium watch dial

lantern mantle

uranium powder and pellet



Answer

The Fiesta ware contains uranium and is radioactive. The watch has radium on the hands and numbers. The resulting glow made it possible to read the time in the dark. Unfortunately, the radium at one time was applied by having workers (usually women) lick the radium to stick it to the hands and numbers. It was common for the workers to end up with cancer of the tongue. Peerless lantern mantles have thorium in them which is radioactive. Although Coleman mantles used to have thorium, this is no longer the case. Thus the Peerless mantles are radioactive and the Coleman are not but some claim the Peerless mantles are brighter. Since all uranium isotopes are radioactive, the ore is radioactive and also sets off the Geiger counter.

Materials and Images. For image, see Station 16.
https://www.gqelectronicsllc.com/comersus/store/comersus_viewItem.asp?idProduct=4579