



Radioactivity

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SCH 4U1

Mr. Dvorsky



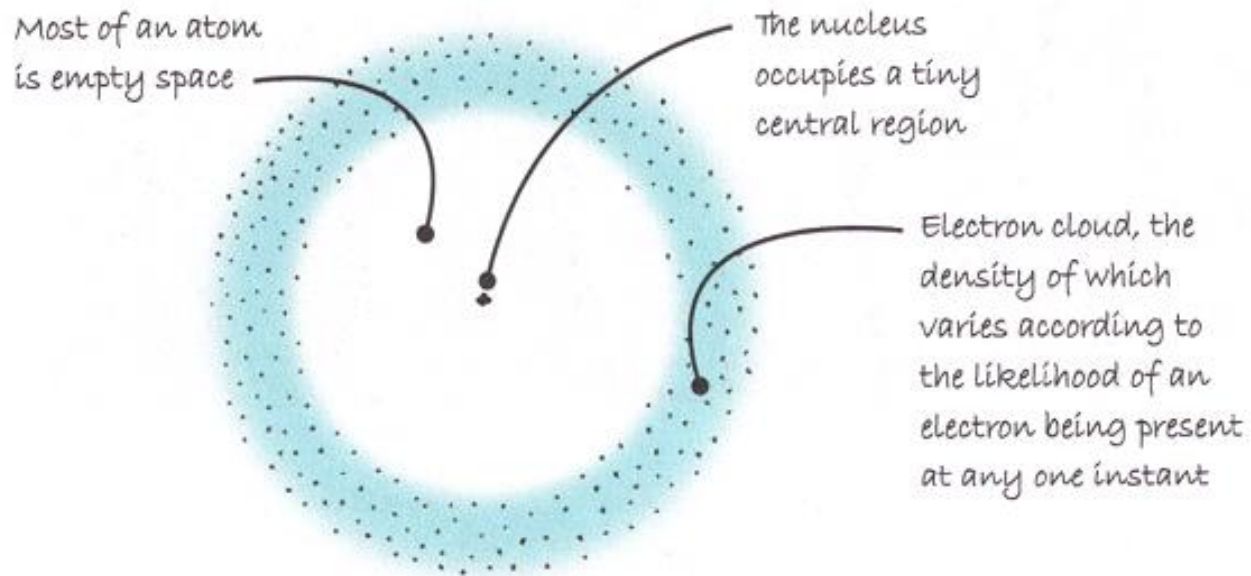
- Life on Earth is dependent on energy from the Sun.
- The Sun emits 3.8×10^{26} joules every second.
- How the Sun accomplishes this was a mystery to scientists for many years.
- Calculations showed that this could not be due to combustion or some normal chemical reaction – if so the Sun would have used up its fuel long ago.



- Radioactivity was discovered by Henri Becquerel in 1896
- Marie Sklodowska Curie isolated a radioactive element from uranium ores
- Rutherford studied the radioactive emissions and suggested there were several types.

Some review...

Recall the modern model of the atom:



NUCLEUS: The nucleus of an atom consists of positively charged protons and uncharged neutrons. The numbers of these depend on the chemical element of which it is an atom.



The Analogy: A Stadium-Sized Atom

If an atom had a diameter of 500 feet—roughly the dimensions of a large sports stadium—then its nucleus would be about the size of the ball in the referee's whistle. This is true for the atoms of nearly all elements, although for just a handful, the nucleus would be slightly larger or smaller. The electrons would be no larger than specks of dust, moving around anywhere within the stadium, although they would be more likely to be located at some particular distances from its center than others.



What Holds Atoms Together?

Electrons, being negatively charged, are held in atoms by electrostatic attraction toward the nucleus, which is positively charged because of the presence of protons. The nucleus itself is held together by the mighty nuclear force.

How is it that protons, which should not hang out together at close quarters, do so in the nucleus of every atom?

Inside an atomic nucleus, an intense conflict plays out between two powerful forces. These are the electromagnetic force—which causes like charges (such as protons) to repel and unlike charges to attract—and the nuclear force, which pulls protons and neutrons together. Normally, the nuclear force wins out...

1 THAT DAY IN THE NUCLEUS...

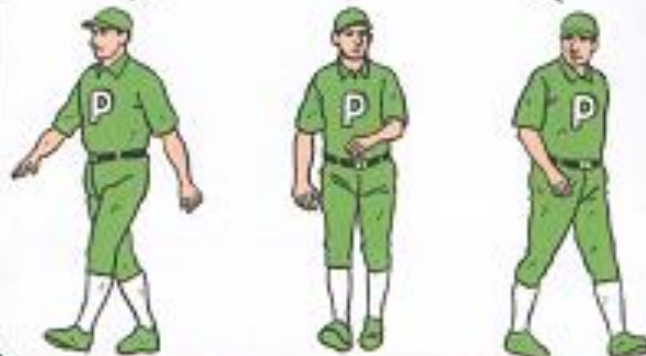
1

I HATE YOU ALL. YOU'RE REPELLENT. GOODBYE!!!



2

THIS ELECTROMAGNETIC FORCE IS DRIVING US APART...



EFFECTS OF THE ELECTROMAGNETIC FORCE

Because the electromagnetic force causes like electrical charges (positive-positive or negative-negative) to repel, the positively charged protons in the nucleus are constantly pushing away from each other.

3

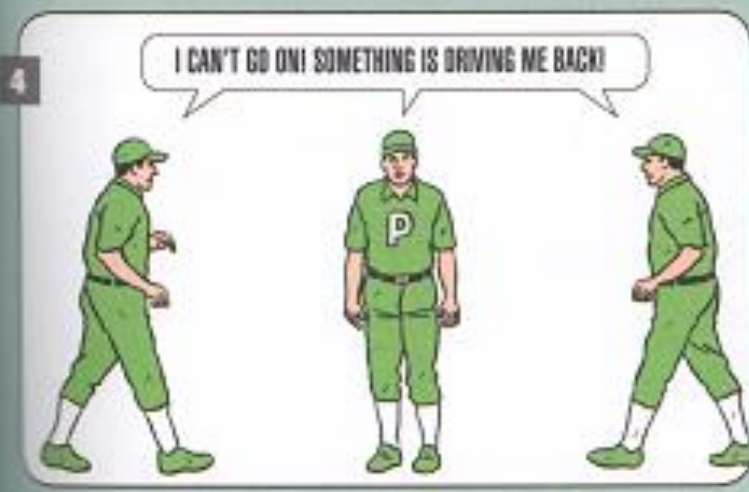
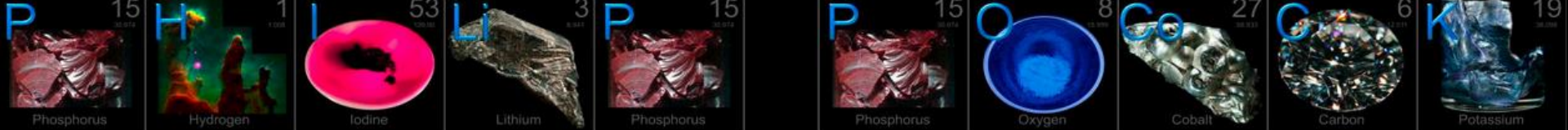
HANG ON...





EFFECTS OF THE NUCLEAR FORCE

Fortunately, the even more powerful nuclear force overrides the electromagnetic force and pulls all the protons and neutrons together. If this didn't happen, the world as we know couldn't exist, because any atoms that formed would immediately break up. The nuclear force is closely linked to (some physicists consider it a "leakage" of) yet another force that operates inside protons and neutrons known as the "strong" force (see Composite Particles, page 23).



A LOVE-HATE RELATIONSHIP
Thus, the protons and neutrons are held tightly in a compact ball. Most nuclei remain like this forever or at least for billions of years. Only in a minority does the conflict between the electromagnetic and nuclear forces eventually cause the nucleus to break up, in what is called radioactive decay (see page 16).



Radioactivity

Not all atoms are stable. While most are likely to last for hundreds of billions of years, some contain a particular combination of protons and neutrons in their nuclei that makes them unstable—this is because of conflicts between the forces operating inside the nuclei (see page 14). As a result, the nuclei of these atoms eventually disintegrate, or at least change in some way—in a process called radioactive decay.

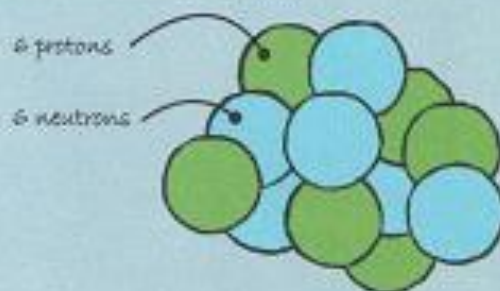
Radioactive Decay

- Unstable atoms that are liable to undergo radioactive decay are called radioactive isotopes –isotopes being forms of chemical elements
- Most naturally occurring elements have several radioactive isotopes as well as one or more stable forms
- A few with particularly large atomic nuclei, such as uranium and radium exist only as radioactive isotopes

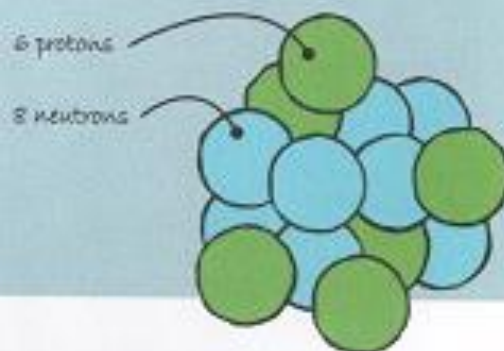
What are Isotopes?

Each chemical element can exist in a number of different forms called *isotopes*. These vary in having different numbers of neutrons in their atomic nuclei. Isotopes have names like oxygen-14 or lead-208—the number after the name of the element denotes the total number of protons and neutrons in the atomic nuclei of that isotope. Some isotopes are stable, others unstable. For example, carbon-12—by far the most common isotope of carbon—is stable, while carbon-14—a much less common isotope—is unstable and will eventually decay.

Carbon-12 nucleus (stable)



Carbon-14 nucleus (unstable)





- When radioactive isotopes decay, they emit energetic particles and sometimes also emit some high-energy radiation.
- As they decay, they are sometimes transferred into the atoms of a different element, and often generate a lot of heat – a pellet of radium will glow in the dark and produce heat for centuries.

Decay Reactions

Types of Radioactive Decay

When radioactive isotopes decay, their nuclei usually emit one of two types of particles, called alpha and beta particles. They may also give off gamma rays. These three types of emission vary in how energetic, penetrating, and hazardous to health they can be.

Alpha particle
(two neutrons and two
protons): not very penetrating
and not dangerous unless
source is eaten or inhaled



Alpha Decay

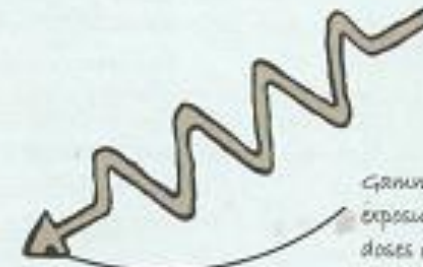
In alpha decay, emission of an alpha particle means that the atomic nucleus of the daughter isotope has two fewer protons than the parent nucleus. Consequently, the daughter is an isotope of a different element from the parent—one with an atomic number two lower than that of the parent. For example, when an isotope of polonium (atomic number 84) undergoes alpha decay, the daughter is an isotope of lead (atomic number 82).

Beta particle (electron):
can penetrate living tissue and
may cause damage



Beta Decay

In beta decay, as an electron flies out of the parent nucleus, one of the neutrons (shown here as light blue) changes into a proton (green). Because this increases the number of protons in the nucleus by one, the daughter is an isotope of a different element from the parent—one with an atomic number one higher than that of the parent. Thus, when an isotope of carbon (atomic number 6) undergoes beta decay, the daughter is an isotope of nitrogen (atomic number 7).



Gamma rays:
exposure to any more than small
doses of these can be a serious
health hazard

Gamma Decay

Gamma radiation is a highly energetic form of electromagnetic radiation (see page 32)—a type of wave rather than a particle. Radioactive isotopes never emit gamma rays on their own but frequently emit them alongside alpha or beta particles. Unlike alpha and beta decay, the emission of gamma radiation has no effect on the number of protons or neutrons left in the nucleus. Instead, gamma ray emission converts the nucleus from a higher, unstable energy state into a lower, more stable one.

Can be Beta Minus Decay $\rightarrow e^-$

Can be Beta Plus Decay $\rightarrow e^+$