Roentgen's experiment (correct spelling):

Cathode Ray Tube: an electrical setup that produces a stream of electrons
("cathode rays" are electrons)

Roentgen discovered X-Rays. (X for unknown)
His cathode ray tube was emitting X-Ray's
He noticed that these X-rays were making a fluorescent material glow in his lab, even when the source was covered by a black cardboard barrier.

Becquerel: Found that a chunk of uranium caused film to expose, even in total darkness

Radioactive Atoms:

- Have an unstable nucleus
- Emit particles and energy
- Really big nuclei (like Uranium and Plutonium) are unstable, so pieces fly out of them

Electromagnetic Spectrum:

Electromagnetic Radiation is light. X-rays are light, radio waves are light, UV rays are light – they are all the same thing, just different frequencies (and different energy).

Memory device: "Rap music irritates very ugly X grandmas."

Low Energy	R M I V U X G	High Energy
Low Frequency		High Frequency
(long wavelength)		(short wavelength)

R = radio waves
M = microwaves
I = infrared
V = visible
U = ultraviolet
X = X rays
G = gamma rays

Ionizing Radiation: high energy radiation, can knock electrons out of atoms to form ions, can cause DNA mutations and other cell damage. UV and higher is ionizing radiation. So is alpha, beta, and neutron radiation.

Nuclear Radiation
Particles and energy give off by an unstable nucleus of an atom

Radioactive Decay
This is when an atom's nucleus 1) gives off radiation and 2) becomes a new element.

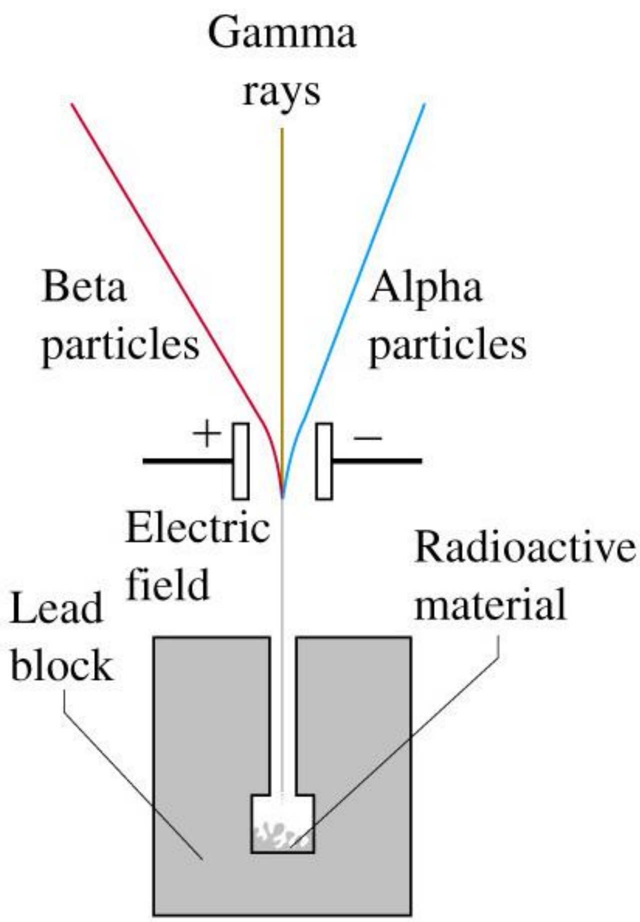
Example: Uranium gives off alpha particles and becomes Thorium.

Rutherford's Experiment w/ Radioactive Decay
He used magnets to separate a stream of radiation into three separate streams.

What he found: <u>There are three types of radiation.</u>
The types of radiation deflect differently depending on the charge of the particles.

Radiation can be positive (alpha), negative (beta), or neutral (gamma).

Neutral (gamma) does not deflect at all in a magnetic field, and the charged ones deflect in opposite directions.

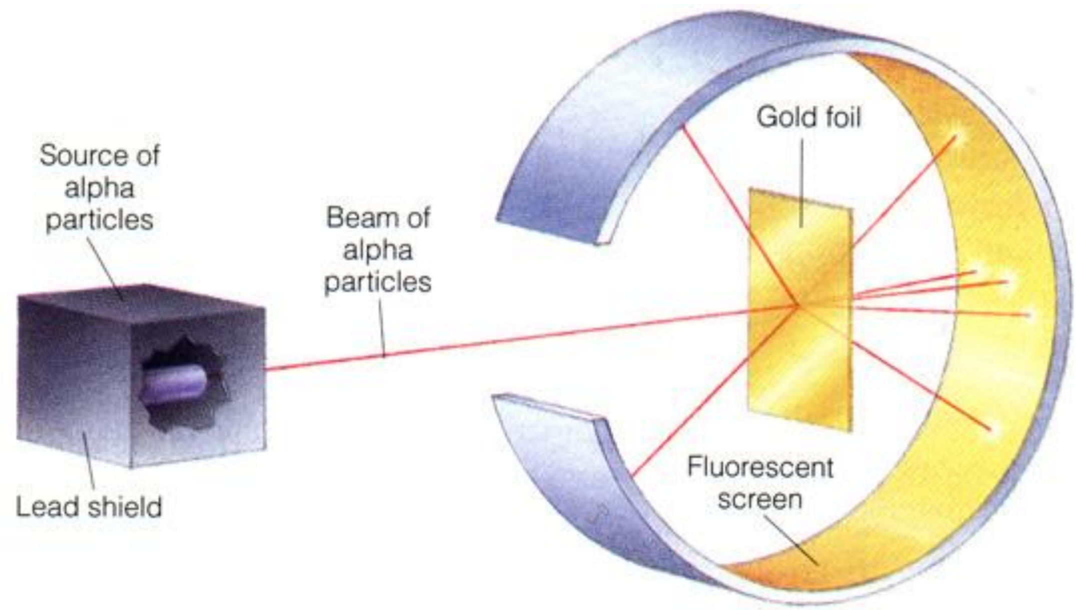


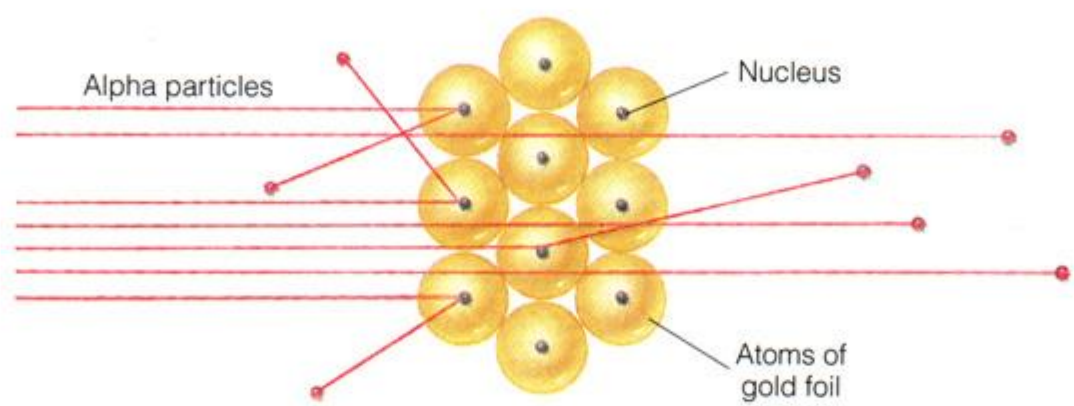
5. Used to think <u>atoms</u> were the smallest particles, now know that they are made up of <u>proton (+)</u>, <u>electron (-)</u>, and <u>neutron (uncharged)</u> particles.

A.3 Rutherford's Gold Foil Expt:

- He decided to shoot alpha particles (+) at gold foil. He noticed the following:
  - Most of them went right through the foil.
  - Some were deflected to the side.
  - A few were deflected straight back.
- His explanation:
  - most of the atom is empty space (so most can go through)
  - the atom has a **small, positive nucleus** that deflects the positive alpha particles if they happened to come close enough (like charges repel).

Emphasis: The discovery of the nucleus was huge. Before that people thought atoms were solid.





2. Rutherford's new model had a <u>nucleus</u> at the center and was somewhat like the <u>solar system.</u>

Notes A.4

1. Subatomic Particles:

Draw a lithium atom. (3 protons, 4 neutrons, 3 electrons)
Label the particles.

protons: +1 charge, mass = 1 Symbol: ${}^{1}_{1}p$

neutrons: 0 charge, mass = 1 Symbol: ${}^{1}_{0}n$

electrons: -1 charge, mass = 0 Symbol: ${}^{-1}_{0}e$

(actually, its mass is about 0.00055)
(units are g/mol)

2. Atomic number tells us **number of protons.**

3. The number of **neutrons** may be different in the nucleus, so the name for atoms having different numbers of **neutrons** but the same number of protons is an **isotope**.
(isotopes are the different forms of an element)

4. Atomic mass tells us **protons + neutrons**.

5.

atom	protons	neutrons	electrons	mass
C-12	6	6	6	12
C-14	6	8	6	14
U-235				
Sr-86				

A.5

1. Isotope average mass

Example: Magnesium (Mg). Has 3 stable isotopes.

Isotope	**Mass**	**Abundance**
Mg-24	23.99	0.7899
Mg-25	24.99	0.1000
Mg-26.	25.99	0.1101

Abundance of 0.7899 means that 78.99% of all Mg atoms are Mg-24 isotope.
10.00% are Mg-25, and 11.01% are Mg-26.

Solving for the average:
Do not add them together and divide by 3. That doesn't work, because you have more Mg-24 than the others, so that will affect the average more. Therefore, you have to use a weighted average.

How to do the weighted average:

1) multiply mass x abundance for each isotope
2) add up all of those numbers.

Isotope	**Mass**		**Abundance**		
Mg-24	23.99	x	0.7899	=	18.9497
Mg-25	24.99	x	0.1000	=	2.4990
Mg-26.	25.99	x	0.1101	=	2.8615
Total					24.3102 g/mol

Notice that the Mg-24 isotope adds in a larger number to the total – that makes sense, because the most abundant isotope should affect the answer the most.

Reality check: Your average should be close to the isotope masses. If your answer is 2431 g/mol, then you have a nonsensical answer. It is probably because you multiplied too many things together at once or forgot to convert from percent to decimal
(i.e. 15% = 0.15)

Radioactivity (goes in notebook – not on yellow sheets)

Radiation: Particles or energy emitted by a source

- Can be in particle form, or it can be just energy waves (light)

Nuclear Radiation: Particles or energy emitted from the nucleus of an atom

- An unstable nucleus will emit radiation

3 Types of Radiation

Alpha
^4He
Positive
Blocked by paper
Largest mass
Does the most damage if you eat it or breath it in (busts up cells)
Emitted by large nuclei – a nucleus is unstable if it is too big, and releasing part of itself as an alpha particle makes it smaller

Beta
An electron
Negative
Very small mass
Goes through paper, but glass blocks it

Gamma
No mass
All energy
High energy light waves
Goes through paper and glass
Stopped by lead if it's thick enough
Higher energy than X-Rays
Damages cells
High doses are lethal
Lots of gamma radiation released in nuclear reactions – heats up the surroundings

B.1

1. <u>Background Radiation</u>
   Constant, natural radioactivity
   Some sources of background radiation:
   - high energy particles from space
   - radioisotopes in soil and rocks (especially uranium)
   - radioisotopes in atmosphere (radon)
   - radioisotopes in food

2. <u>REM</u>
   - Unit that measures <u>ionizing radiation</u> exposure
     (radiation that can cause cell damage)
   - U.S. Average level: 360 mrem per year
     1 rem = 1000 mrem

High levels increase cancer risk.
REALLY high levels cause radiation sickness
(kills immune system, causes death, etc)

B.4 & B.5

1. Natural radioactive decay

Alpha / Beta / Gamma: already covered in previous notes.

Examples for alpha / beta decay reactions.

B.6

1. Radon

Radioactive gas.
Cancer risk – radon is the second leading cause of lung cancer after smoking.

Comes from Uranium in soil (the U undergoes alpha decay several times)

- How many alpha decays does it take to go from U to Rn?

Iowa has the highest average radon levels in the U.S. (from uranium in our soil)

Radon can be cheaply tested in your home.
It costs $800-2500 to install residential radon reduction systems
(can reduce radon by 99%).
They often work by venting air away from under the basement and keeping air concentrations low.

C.4
1 – Rutherford achieved transmutation of atoms, converting one element to another.

Ex: $^{4}_{2}He + ^{14}_{7}N \longrightarrow ^{17}_{8}O + ^{1}_{0}n$ (a reaction performed in a lab)
O-17 is a stable isotope of oxygen, but in nature it is very rare.

2. 4 particles involved: see page 457 in book – they are listed in Building Skills 457.
(look them up and fill them in on your own)

D.1
1. Fission
Splitting an atom's nucleus into two smaller nuclei. 0020
This is the type of reaction that happens in power plants and bombs.
(opposite of fusion, where two nuclei are combined)

Ex: $^{235}_{92}U + ^{1}_{0}n \longrightarrow Energy + ^{141}_{56}Ba + ^{92}_{36}Kr + 3^{1}_{0}n$
(note – one neutron is added, but three are produced.)
(also note – the masses add up to 236 on each side. Add it up for yourself to verify.)

2. The strong force holds protons and neutrons together.

3. $E = mc^2$

E = energy, m = mass, c = speed of light c = 300,000,000 m/s = 670,000,000 miles/hr
Mass can be converted to energy.
A little bit of mass is A LOT of energy.
In nuclear reactions, a little bit of the mass is converted to energy (hence nuclear power).

4. Chain reaction
- Neutrons start the reaction… and the reaction produces more neutrons, so they start more reactions.

5. Critical Mass

A chain reaction cannot start unless you have enough U-235 (or another fissile material).
The reason: the neutrons released in the first reactions might not hit another U-235 nucleus if there are only a few scattered around – they might just escape into the environment. But, if there are so many of those nuclei around that the neutrons basically can't miss, then you have critical mass and you can have a chain reaction.

Rapidly Expanding Chain Reaction 1 n + U-235 → 3 n + products + energy

Bombs are REALLY FAST rapidly expanding chain reactions – in other words, an explosion.
They expand really fast: one reaction becomes three, 3 become 9, 9 become 27, etc.
This only works if you have a really high concentration of U-235 (**90%** or more).
Otherwise, the neutrons don't always hit another U-235 to keep speeding up the rxn.

FYI: power plants use **3%** or **4%** U-235 concentration (gives a nice steady flow of energy)

- Not even close to enough to make a rapidly expanding chain reaction (explosion).

Tracers Notes
(Tracers: radioactive isotopes fed to a patients to make medical images)

1. **Tracer studies:**

Suitable isotopes must satisfy the following:

a. Low energy gamma ray emitter (safer than alpha/beta)
b. short half life (so you can see it in a scan)
c. low dose (safer)
d. goes to a particular area of body (otherwise, no useful pattern in picture)

2. **Tracer uses**

- Detecting tumors
- Find blood clots
- diagnose thyroid problems
- plus others (see pg 455)

(side topic – not on notes)
Technetium-99m

- Emits lower energy gamma rays
- the most used medical tracer
    - Has a tendency to go straight to tumors.
    - So, you feed it to somebody, then you use a machine to check what part of their body is emitting gamma rays.
- Half life 6 hours – so you have to make it from Mo-99 (bombard with electrons)
- Mo-99 has half life of 66 hours - does not occur naturally. Made from U-235.
- By the way – Technetium has no stable isotopes. It is not found in nature – the smallest element that is not found in nature. Yet, scientists and doctors figured out a way to put it to good use in medicine.

D.2

1. Most power plants make power by producing heat to boil water which then turns a turbine.

2. Expanding vs Limited reactions:

Regular Chain Reaction (limited reaction):
Happens in a power plant. Provides a steady stream of energy.

Rapidly Expanding Chain Reaction:
The chain reaction speeds up really fast and causes an explosion (bomb).

3. Parts of a power plant

A. Fuel Rods:

Contains the uranium (in UO_2 form)

Only about 4% of UO_2 is fissionable (U-235), so it allows a chain reaction but not a nuclear explosion.

B. Control Rods:

Absorbs neutrons – these can slow down or stop the reaction very quickly.
No neutrons = no reaction.

C. Moderator

Slows down neutrons. Makes them more likely to hit U-235 – makes reaction work better.

D. Generator

Converts mechanical energy from turbine into electrical energy

E. Cooling System

Cools / condenses the steam back to water so it can be reused.

D. 3

1. Fusion
   - When 2 (or more) small atoms combine to make one bigger one.
   - Fusion occurs in stars – not on earth. (requires 10,000,000 °C)
   - Would be a great power source (clean) if we can figure it out

2. 4 <u>hydrogen</u> atoms (and 2 electrons) combine to make 1 <u>helium</u> atom and <u>energy.</u>

D.5

1. High level nuclear waste disposal

   High level = most radioactive waste (spent nuclear fuel)

   Disposal…..??? We still haven't figured out a really good way to dispose of it.

2. Low level nuclear waste disposal

   Low level = less radioactive – includes used lab clothing, air filters, etc.

   Can safely be sealed and buried 20 ft underground.