AMSAT CHEM 1H TOPIC#4
ATOM - NUCLEAR CHEMISTRY NOTES

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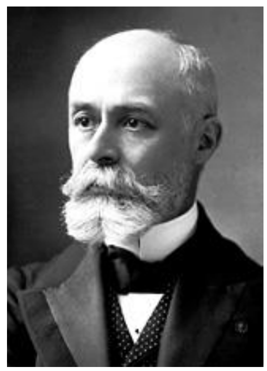
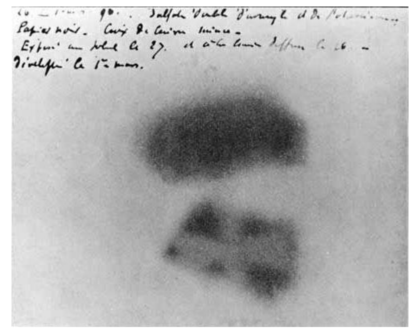
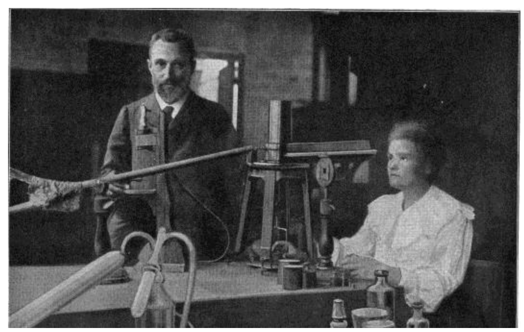
RADIOACTIVITY SECTION #1

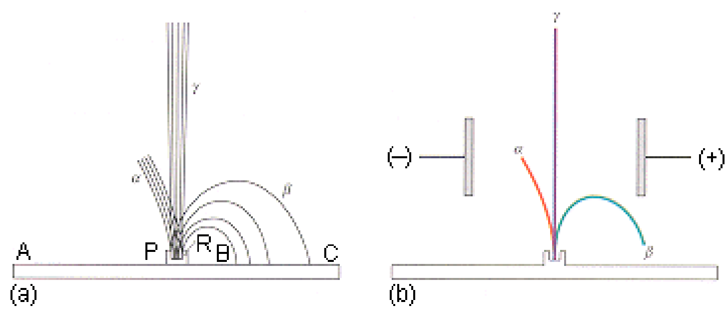
- Henri Becquerel
  - Discovered radioactivity
    - Spontaneous emission of radiation from an element
  - Placed uranium sample on photographic plate by accident
    - When developed showed rough outline of sample





- Marie Sklodowska Curie and husband Pierre
  - Worked with Becquerel
  - Discovered radium and polonium
- Radioactivity
  - Fundamental changes to atom
  - Chemical and physical properties change
- Ernest Rutherford
  - Placed radioactive sample between two charged plates
    - Some radiation deflected towards negative plate
      - Alpha radiation
    - Some radiation deflected towards positive plate
      - Beta radiation
  - Gamma discovered later
    - Not affected by charged plates





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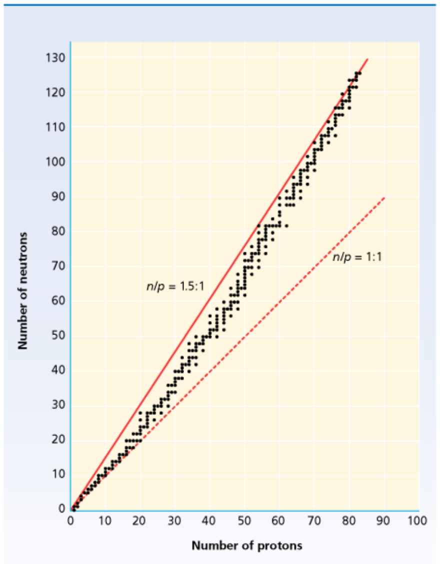
NUCLEAR STABILITY SECTION #2

- Nuclear reactions
  - Change the composition of the nucleus
  - Results in a new element
  - Three types of radiation
    - Alpha
      - Helium nucleus
      - ${}^{4}_{2}He^{2+}$ (or just ${}^{4}_{2}He$)
    - Beta
      - High speed electron from nucleus
      - ${}^{1}_{0}n^{0} \rightarrow {}^{1}_{1}p^{+} + {}^{0}_{-1}e^{-}$
      - Increases the atomic number of the parent atom by 1
    - Gamma
      - High energy electromagnetic wave (light)
  - Nucleons
    - The protons and neutrons in the nucleus
    - Nuclide
      - Atom in a nuclear chemistry
  - Stable nuclei
    - Not radioactive
    - Neutrons are "glue" holding nucleus together
      - Strong nuclear force
    - Elements 1-20
      - Almost equal numbers of neutrons and protons



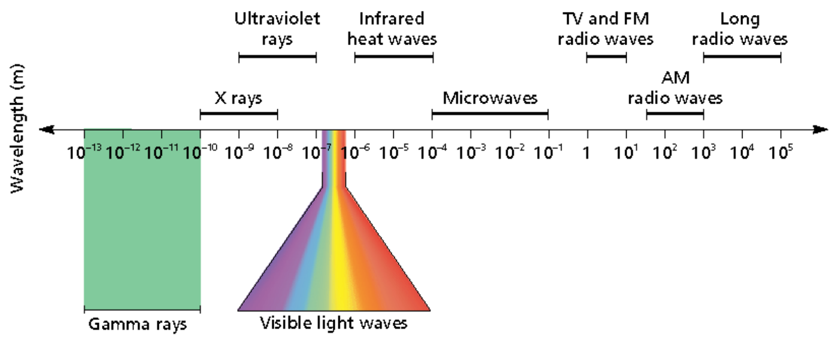
  - Unstable nuclei
    - Atomic number exceeds 83
      - Radioactive
      - No number of neutrons can hold the nucleus together
    - Too few neutrons
      - Emit beta radiation
  - Rule (Band of stability)
    - Nuclides with more/less neutrons than most common stable isotope are unstable

TYPE OF RADIOACTIVE DECAY/NUCLEAR REACTIONS SECTION #3

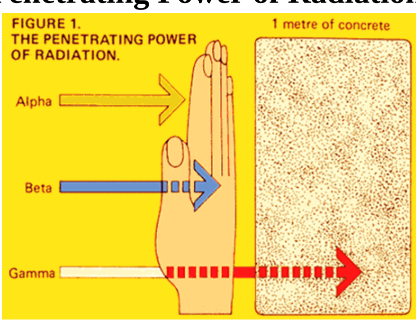
- Three types
  - Alpha
    - ${}^{4}_{2}He^{2+}$ (helium nucleus) or ${}^{4}_{2}\alpha$
    - Symbol: α
    - Charge: +2
    - Penetrating power: low, stopped by paper

- Source: nucleus splits into two nuclei, one of which is the alpha particle

- Beta
  - $^{0}_{-1}e$ or $^{0}_{-1}\beta$
  - Symbol: β
  - Charge: -1
  - Penetrating power: medium, stopped by heavy clothing
  - Source: neutron in nucleus breaks down into a proton and a high speed electron
    - $^{1}_{0}n \longrightarrow {}^{1}_{+1}p + {}^{0}_{-1}e$
- Gamma
  - $^{0}_{0}\gamma$
  - Symbol: γ
  - Charge: 0
  - Penetrating power: high, 6 inches of lead or 6 feet of concrete



Penetrating Power of Radiation



Effect of Whole body Exposure to a Single Dose of Radiation

Dose (rem)	Probable effect
0–25	no observable effect
25–50	slight decrease in white blood cell count
50–100	marked decrease in white blood cell count
100–200	nausea, loss of hair
200–500	ulcers, internal bleeding
> 500	death

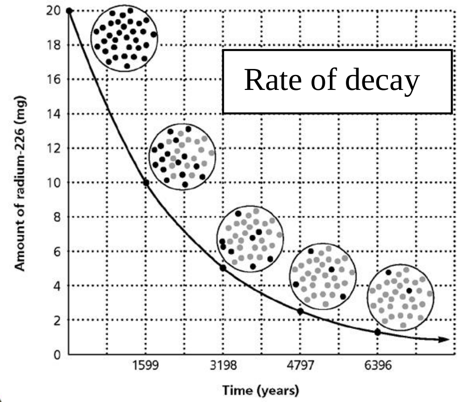
Units of Radioactive Measurement

Units	Measurements
Curie (C)	radioactive decay
Becquerel (Bq)	radioactive decay
Roentgens (R)	exposure to ionizing radiation
Rad (rad)	energy absorption caused by ionizing radiation
Rem (rem)	biological effect of the absorbed dose in humans

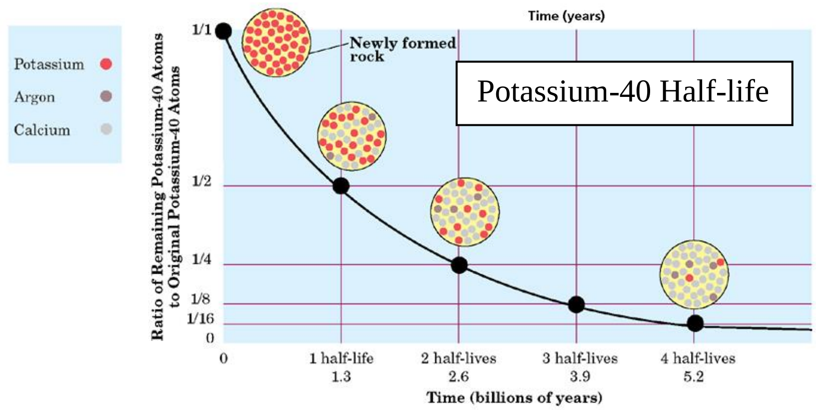
Radioactive Nuclide Emissions

Type	Symbol	Charge	Mass (amu)
Alpha particle	$^{4}_{2}He$	2+	4.001 5062
Beta particle	$^{0}_{-1}\beta$	1–	0.000 5486
Positron	$^{0}_{+1}\beta$	1+	0.000 5486
Gamma ray	γ	0	0

- Radioactive decay
  - Decay by emission of one or more of the three types of radiation (alpha, beta, gamma)
    - Geiger-Muller counters
      - Detect radiation



- Half-life ($t_{1/2}$)
  - Time required for half the atoms of a radioactive element (nuclide) to decay.
  - $n_{1/2}$ = time of decay/$t_{1/2}$ or if the measure is a fraction of the initial amount then use fraction to determine the number of half-lives the material has gone through.
  - $mass_F = (½)^t(mass_I)$



- **<u>Sample Problem 3.3</u>** – Half-life
  Phosphorus-32 has a half-life of 14.3 days. How many milligrams of phosphorus-32 remain after 57.2 days if you start with 4.0mg of the isotope?
  Ans: 0.25mg

Half-lives for some Radioactive Isotopes

Isotope	Half-life	Radiation emitted	Isotope formed
Carbon-14	5.715×10^3 y	β^-, γ	nitrogen-14
Iodine-131	8.02 days	β^-, γ	xenon-131
Potassium-40	1.28×10^9 y	β^+, γ	argon-40
Radon-222	3.82 days	α, γ	polonium-218
Radium-226	1.60×10^3 y	α, γ	radon-222
Thorium-230	7.54×10^4 y	α, γ	radium-226
Thorium-234	24.10 days	β^-, γ	protactinium-234
Uranium-235	7.04×10^8 y	α, γ	thorium-231
Uranium-238	4.47×10^9 y	α, γ	thorium-234
Plutonium-239	2.41×10^4 y	α, γ	uranium-235

<u>Practice</u>

(1) The half-life of polonium-210 is 138.4 days. How many milligrams of polonium-210 remain after 415.2 days if you start with 2.0mg of the isotope? (Ans: 0.25mg)

(2) Assuming a half-life of 1599 years, how many years will be needed for the decay of 15/16 of a given amount of radium-226? Ans: 6396 years

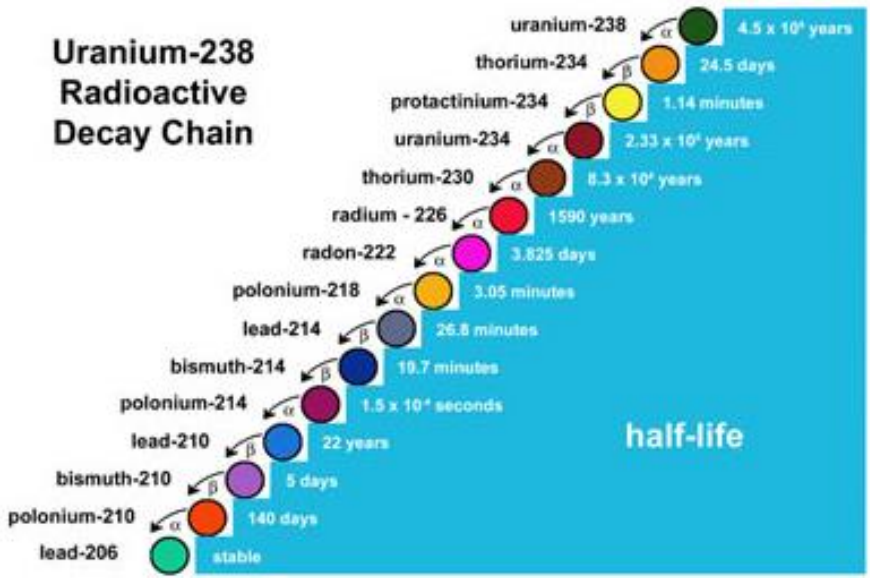
(3) The half-life of radon-222 is 3.824 days. After what time will one-fourth of a given amount of radon remain? Ans: 7.648 days

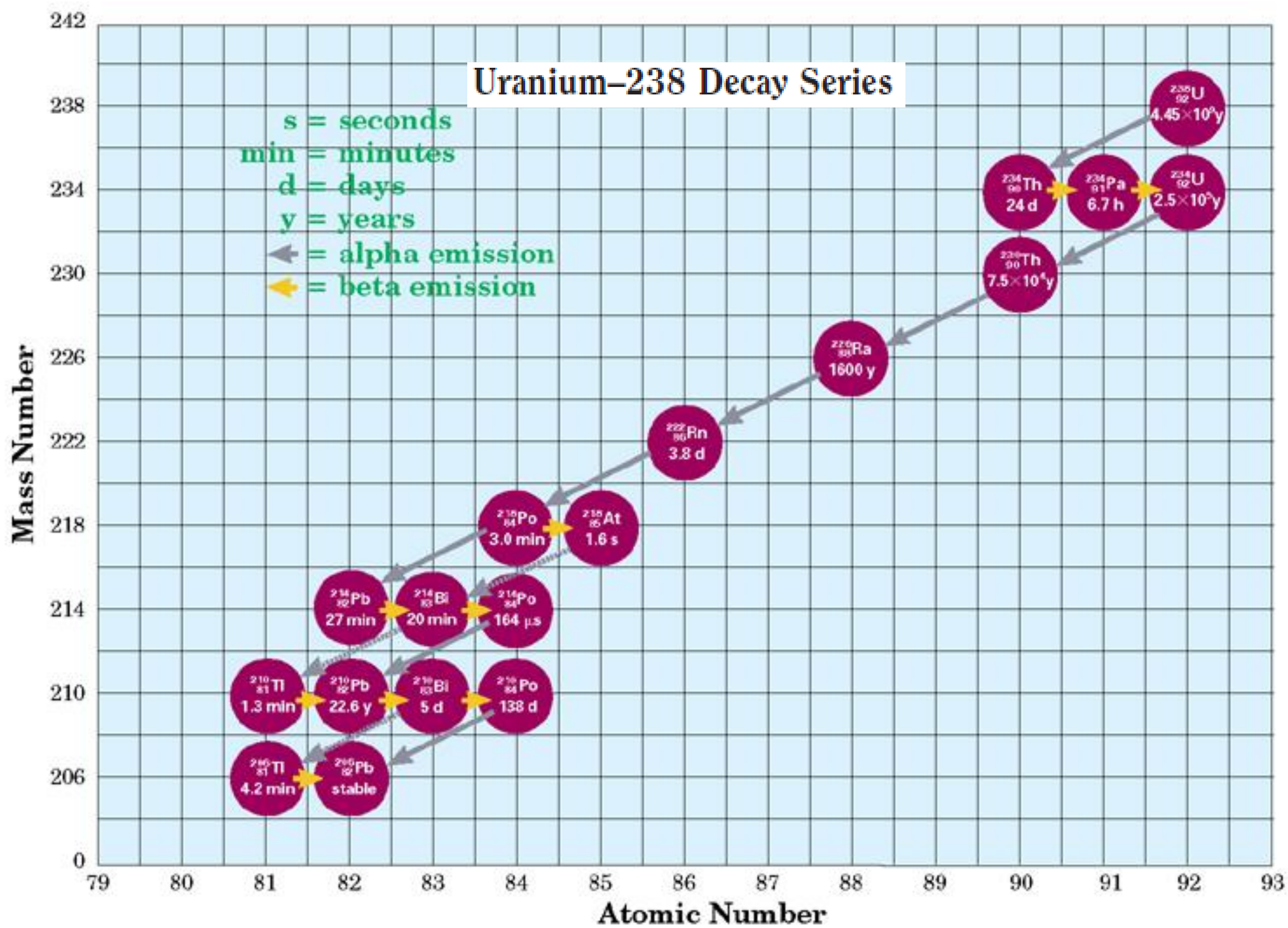
(4) The half-life of cobalt-60 is 10.47 min. How many milligrams of cobalt-60 remain after 104.7min if you start with 10.0mg? Ans: 0.00977mg

(5) A sample contains 4.0mg of uranium-238. After 4.46×10^9 years, the sample will contain 2.0mg of uranium-238. What is the half-life of the sample? Ans: 4.46×10^9years

(6) A sample contains 16mg of polonium-218. After 12min, the sample will contain 1.0mg of polonium-218. What is the half-life of polonium-218? Ans: 3.0min

- Decay Series
  - A series of radioactive isotopes produced by successive radioactive decay until a stable nuclide is formed.





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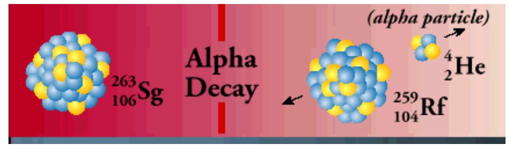
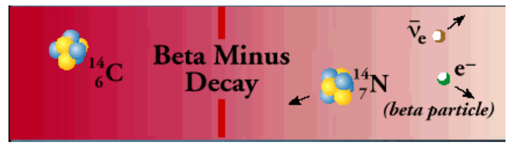
- Nuclear Equation (decay reaction)
  - Mass number and atomic numbers are equal on both sides
    - Sum of reactants = sum of products
      - Reactants (parent nuclide) produce products (daughter nuclide)
    - Alpha decay
      - Mass number decreases by 4 and atomic number decreases by 2
        - ${}^{263}_{106}Sg \rightarrow {}^{259}_{104}Rf + {}^{4}_{2}He$ (or ${}^{4}_{2}\alpha$)
          - 263 = 259 + 4
          - 106 = 104 + 2



      - Beta decay
        - Mass number stays the same while atomic number increases by 1
        - ${}^{131}_{53}I \rightarrow {}^{131}_{54}Xe + {}^{0}_{-1}e$ (or ${}^{0}_{-1}\beta$)
          - 131 = 131 + 0
          - 53 = 54 - 1



  - **<u>Sample Problem 3.4</u>** – Balancing Nuclear Reactions

(1) ${}^{230}_{93}Np \rightarrow {}^{0}_{-1}\beta +$ ____

(2) ${}^{9}_{4}Be + {}^{4}_{2}He \rightarrow$ ____

(3) ${}^{32}_{15}P +$ ____ $\rightarrow {}^{33}_{15}P$

(4) ${}^{236}_{92}U \rightarrow {}^{94}_{36}Kr +$ ____ $+ 3{}^{1}_{0}n$

(5) ${}^{43}_{19}K \rightarrow {}^{43}_{20}Ca +$ ____

(6) ${}^{233}_{92}U \rightarrow {}^{229}_{90}Th +$ ____

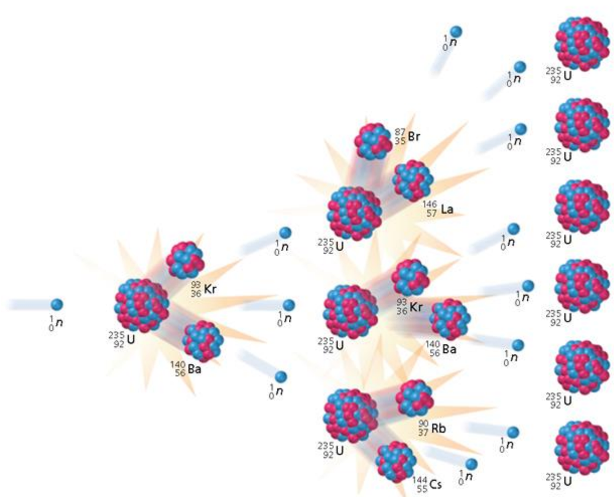
(7) ${}^{11}_{6}C +$ ____ $\rightarrow {}^{11}_{5}B$

(8) ${}^{13}_{7}N \rightarrow {}^{0}_{+1}\beta +$ ____

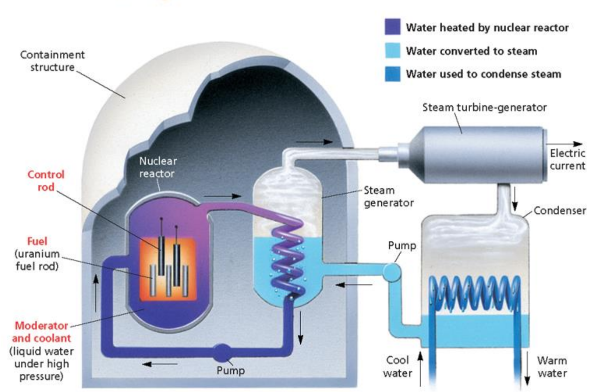
(9) Write the nuclear equation for the release of an alpha particle by ${}^{210}_{84}Po$.

(10) Write the nuclear equation for the release of a beta particle by ${}^{210}_{82}Pb$.

- Nuclear reactions
  - Fission
    - Very heavy nucleus splits into more stable nuclei of intermediate mass
    - Chain reaction
      - A reaction where a product of one reaction starts another reaction
        - Neutron emission
        - Produces daughter nuclei
    - Nuclear reactors (Power Plant)
      - Use fission to generate electricity



Fission induction of uranium-235 by bombardment with neutrons can lead to a chain reaction when a critical mass of uranium-235 is present.



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        - Heat from nuclear reaction turns water into steam and moves a turbine
  - Fusion
    - Light-mass nuclei combine to form a heavier nuclei
      - More energy than fission reaction
      - Reaction that fuels the sun
        - $^{1}_{1}H + ^{1}_{1}H + ^{1}_{1}H + ^{1}_{1}H \rightarrow ^{4}_{2}He$ + energy
          - Energy comes from the equation $E = mc^2$
            - Mass is converted into energy
            - Einstein

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