Nuclear Chemistry

NOT Nucular chemistry!

Types of radioactive decay

- Alpha (α) decay – the nucleus emits a helium nucleus (α particle).
  - $^{226}_{88}Ra \rightarrow ^{4}_{2}He + ^{222}_{86}Rn$
  - low energy process
  - can be blocked by skin or clothing or paper
  - can be dangerous if inhaled or ingested

Types of radioactive decay

- Beta (β) decay – the nucleus emits an electron (β particle)
  - $^{14}_{6}C \rightarrow ^{14}_{7}N + ^{0}_{-1}e$
  - essentially the same as a neutron converting into a proton
    - $^{1}_{0}n \rightarrow ^{1}_{1}p + ^{0}_{-1}e$
  - higher in energy than α decay
  - can be blocked by heavy clothing or plastic
  - can also refer to the emission of a positron (positively charged electron or anti-electron)

Types of radioactive decay

- Gamma (γ) emission – an excited nucleus releases energy and goes to a lower energy state.
  - highest energy
  - need lead or concrete to block it

Nuclear Equations

- Represent what happens in a nuclear reaction
- nucleon number and charge must be conserved
  - mass numbers on top must be equal on both sides
  - atomic numbers on bottom must be equal on both sides

Nuclear Equations

- Reactant and product nuclei are represented by their nuclide symbols
  - $^{12}_{6}C$ or $^{241}_{94}Pu$
- Other symbols that may be used
  - proton – $^{1}_{1}H$ or $^{1}_{1}p$ or p
  - neutron – $^{1}_{0}n$ or n
  - electron – $^{0}_{-1}e$ or e or $^{0}_{-1}\beta$ or β
  - positron – $^{0}_{1}e$ or $^{0}_{1}\beta$
  - Gamma photon – $^{0}_{0}\gamma$

“Balancing” nuclear equations

- There will be only one thing missing from the equation.
- Fill in the blank by making sure the nucleon number and charge are conserved

234+1 = 235　　235-97 = 138　　94+3(1) = 97

$$^{234}_{92}U + ^{1}_{0}n \rightarrow ^{138}_{56}Ba + ^{94}_{36}Kr + 3\,^{1}_{0}n$$

92+0 = 92　　92-36 = 56　　36+3(0) = 36

7

Radiation Measurement

- Usually measured with a Geiger counter
- Unit is the Curie (Ci)
  - 1 Ci = 3.7ã10^{10} disintegrations s^{-1}
  - being replaced by the Becquerel (SI Unit, Bq,
    1 Bq = 1 dis/s)

8

Biological Effect

- rad (radiation absorbed dose) – amount of radiation absorbed by 1 g of tissue.
  - being replaced by the Gray (SI Unit, Gy, 1Gy = 100 rad)
- rem (radiation equivalent in humans)
  - being replaced by the Sievert (SI Unit, Sv, 1 Sv = 100 rem)
- Actual dose (rem) = rad ã factor

9

Factors

- For β and γ radiation the factor is 1
  - rads and rems are the same
- For α radiation the factor is 20.
- For high speed protons and neutrons the factor is 10.

10

Radiation Exposure

- Always exposed to radiation
  - natural sources – rocks, cosmic sources
- “Artificial” sources
  - X-rays, CAT scans, PET scans
  - TV
  - Cigarettes

11

Radiation Sickness

- Too much radiation
- Whole body exposure
  - 100 rem – temporary decrease in white blood cells
  - >100 rem – nausea, vomiting, fatigue, white blood cell reduction
  - 300 rem – white blood cell count is zero, diarrhea, hair loss, and infection
  - 500 rem – death in 50% of people exposed
  - 600 rem – all humans exposed are dead within a few weeks

12

half-life of radioactive isotopes

- ½ life is the amount of time it takes for ½ of the nuclei present to decay
  - This number is a constant – it doesn't depend on the amount of substance
  - Example – ^{51}Cr has a half-life of 28 days
    - 100 g at 0 days
    - 50 g at 28 days
    - 25 g at 56 days
    - 12.5 g at 84 days

13

Dating objects by half-lives

- ^{14}C has a half-life of 5730 years.
- Can be used to date object that take in carbon – i.e., living things
- Not useful past about 50,000 years

14

Medical Applications of Radioactivity

- PET scans – Positron Emission Tomography
  - Uses a positron emitter (^{11}C, ^{15}O, and ^{13}N)
  - ingested by the patient and then the machine "sees" where the positrons come from and makes a picture.

15

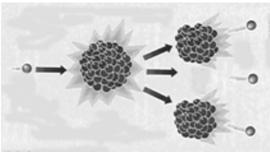
Fusion and Fission

- Nuclear fusion
  - A nucleus breaks apart and releases energy
    - Application of Einstein's equation $E=mc^2$
  - Process used in nuclear reactors
    - controlled reaction
  - Also used in nuclear weapons (atomic bombs)
    - chain reaction

16

Chain Reaction

- One neutron causes a nucleus to split and it produces 2 or more neutrons
- Each of those does the same thing
- and so on
- and so on
- and so on



17

Fusion and Fission

- Nuclear Fusion
  - Lighter nuclei are forced together to make heavier nuclei
  - Process that powers the sun and all the other stars
  - Requires high temperatures (100,000,000K) and pressures

18