

1. Notices

Notices

- Thursday 4:30

Tufts is having a panel on the Iran situation.

"Target: Iran?"

Teach-In

sponsored by TCOWI

What is the reality and what are the myths behind Iran's nuclear program?
What are the real motives of the Bush administration?
What would a US attack mean for Iranians?

Prof. Gary Goldstein will be speaking about the nuclear issue. Prof. Modhumita Roy will talk about nuclear weapons in South Asia. Two Harvard grad students from Iran will be connecting to political issues. Given the heating up of the rhetoric and the Seymour Hersh article in the NewYorker about the build-up to war, this is an urgent issue for all of us.

- **Homework 5 due Tuesday - last assignment**
- **Final May 5 3:30-5:30**

5/10/2006 Physics 6 - G.R. Goldstein - Spr.03Physics 6 - Spring 06 - G.R. Goldstein 1

2. Radioactivity

Radioactivity

- All decays occur randomly - probability distribution characteristic of nuclide and decay products
- Activity=rate of decrease in time = $\underline{A}(t)$
- $\underline{A}$ in units of Curies

  1 Curie $=3.7\times 10^{10}$ disintegrations/sec

  or Becquerels (Bq) SI units
- $\underline{A} \propto N(t)$ (each decay is independent of others)
- How does N(t) change in time?

5/10/2006 Physics 6 - G.R. Goldstein - Spr.03Physics 6 - Spring 06 - G.R. Goldstein 2

3. Nuclear decays

Nuclear decays

- α: (Z,A)$\rightarrow$(Z-2,A-4)+${}_2^4$He
  - Strong or nuclear glue and quantum tunneling
- β: (Z,A)$\rightarrow$(Z+1,A)+e^- also have (Z-1,A)+e^+
  - Weak and based on $n \rightarrow p+e^- + \nu$ *(anti-neutrino)*
- γ: (Z,A)*$\rightarrow$ (Z,A)+γ
  - EM quantum transition
- N: (Z,A) $\rightarrow$ (Z,A-1)+n
- Each with characteristic decay time and energy release (Q value)

5/10/2006 Physics 6 - G.R. Goldstein - Spr.03Physics 6 - Spring 06 - G.R. Goldstein 3

4. Exponential decay

Exponential decay

- $t_{1/2}$ is the half-life
- If N_0 at time 0, $N_0/2$ at $t_{1/2}$
  $N_0/4$ at 2 $t_{1/2}$ $N_0/8$ at 3 $t_{1/2}$ $N_0/16$ at 4 $t_{1/2}$
  or $N_0/2^n$ at time n $t_{1/2}$
- Exponential decay law for many phenomena, especially QM decays (and heat transfer)

$$N(t) = N_0 2^{-\left[\frac{t}{t_{1/2}}\right]} = N_0\, e^{-\left(\frac{0.69\,t}{t_{1/2}}\right)}$$

$$\text{Activity (Bq)} = \frac{0.69}{t_{1/2}} N(t) \quad \text{with t in sec}$$

5/10/2006 Physics 6 - G.R. Goldstein - Spr.03Physics 6 - Spring 06 - G.R. Goldstein 4

5. Decay examples

Decay examples

NUCLEUS	ATOMIC WEIGHT	HALF LIFE	DECAY PRODUCTS
Ra	226	1602 years	alpha,gamma(4%)
C	14	5730 years	beta
Sr	90	28 years	beta
^{3}H	3	12.3 yr	beta
I	131	8 days	beta,gamma
Cs	137	30 yr	beta,gamma
Rn	222	3.8 days	alpha,gamma(0.1%)
U	238	4.50×10^{9} yr	alpha,gamma(23%)
U	235	7.0×10^{8} yr	alpha,gamma
Pu	239	24,400 yr	alpha

5/10/2006 Physics 6 - G.R. Goldstein - Spr.03Physics 6 - Spring 06 - G.R. Goldstein 5

6. Summary of Radiation Measures

Summary of Radiation Measures

Physical quantity	Units	Definition	Remarks
source activity	Curie	3.7×10^{10} disintegrations/sec	radioactivity of 1 gram of radium
	Becquerel	1 disintegration/s	newer Standard Int'l unit
amount of radiation	Roentgen	produces ~2×10^{9} ion pairs in 1 cm^3 air	radiologist's units; amount produced by 1Ci at 1m in 1hr
dose	rad	produces 1/100 J/Kg in biological tissue	human exposure
	Gray	1 J/Kg or 100 rads	new S.I. unit
biological dose	rem	biological effect of 1 rad of gamma rays	approximate measure of biological effect for any radiation
	Sievert	100 rems	New S.I. units

5/31/2006 Physics 6 - Spring 06 - G.R. Goldstein 6

7. Relations among measures

Relations among measures

Order of magnitude estimates or "Rules of thumb"

a. 1 gram of Ra or a 1 Ci source produces 1 R per hour at 1 meter distance;

b. 1 R (of gammas) gives about 1 rem dose (1 rad is about 1 rem); but 1 R (of alphas) gives about 10 rem dose; other radiation is between these extremes;

c. 1 milliCurie of material dissolved in 1 liter of water produces 8 rem/hour (for gammas);

d. 1 rem dose increases the number of cancer deaths by 200 in a population of 1 million people;

e. [surface contamination (uniformly): 1 Ci/m^2 produces 40 rad/hr at height of 1 m] (more variable than others)

Background radiation (cosmic, surroundings) ~100 to 300 mrem/yr

Medical X-ray ~ 10-50 mrem

Acceptable limits ~ 1 rem/yr

Recent item: low level X-rays for airport screening?

5/10/2006 Physics 6 - G.R. Goldstein - Spr.03Physics 6 - Spring 06 - G.R. Goldstein 7

8. Nuclear weapons

Nuclear weapons

- Warheads - A-bombs & H-bombs
  - Hiroshima & Nagasaki
    - 12 - 15 kilotons (1 kt:1000 tons of TNT)
    - ~100,000 deaths (WTC ~600 tons → 6000 deaths)

      (NY Times -F.A. Moscatelli 9/25/01)
  - H-bombs US/USSR tested 10's of Megatons
    - Warheads on missiles now ~ 100-300 kt
    - 6000-7000 currently deliverable
  - Smaller bombs by design or necessity
    - Newer members of nuclear club - India, Pakistan, N.Korea - join US, UK, France, China, Russia + Israel
    - See Bulletin of the Atomic Scientists for annual inventories

5/10/2006 Physics 6 - G.R. Goldstein - Spr.03Physics 6 - Spring 06 - G.R. Goldstein 8

9. Fusion

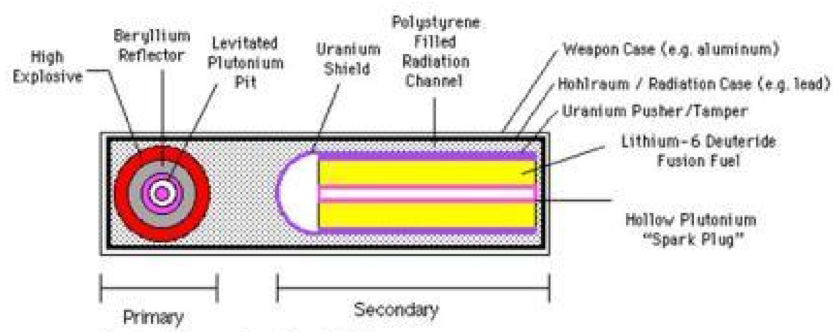
Fusion

- Example - deuteron = d = ${}^{2}_{1}H$ ~ p and n
  - $m_d c^2 < m_p c^2 + m_n c^2$ by 2.2 MeV (binding energy)
  - So n + p -> d + 2.2 MeV (extra KE or radiation)
- Solar energy
  - d + t -> He + n + 17.6 MeV extra energy
  - or ${}^{2}_{1}H + {}^{3}_{1}H \rightarrow {}^{4}_{2}He + {}^{1}_{0}n$ + Energy
  - need cycle at very high temperature to overcome Coulomb repulsion between plus charges
  - Enhance energy by many $N_{avogadro}$ for sun or star
- H bomb

5/10/2006 Physics 6 - G.R. Goldstein - Spr.03Physics 6 - Spring 06 - G.R. Goldstein 9

10. H-bomb or nuclear fusion bomb Teller-Ulam design

H-bomb or nuclear fusion bomb
Teller-Ulam design



Fission-fusion-fission (U238)

5/25/2006 Physics 6 - Spring 06 - G.R. Goldstein 10