Today

Quantifying Radiation

Applications

We need to try to quantify amount of “radiation”

How much ionizing radiation is coming from a source?

How much ionizing radiation has interacted with you?

How much “equivalent” radiation?

How much ionizing radiation is coming from a source?

Old Unit

Curie (Ci) = 3.7×10^{10} decays s^{-1}

New Unit

Becquerel (Bq) = 1 decay s^{-1}

doesn't tell you the type of radiation
just how many "events"

it is like the half-life combined with the amount

How much ionizing radiation has interacted with you?

Easiest to quantify for Gamma Radiation
(remember this also what we are most worried about)

Gray (Gy) = 1 J kg^{-1}

Exposure to 1 J of Gamma radiation per Kilogram of matter

rad = 100 erg g^{-1} (cgs unit) 100 rad = 1 Gy

Need to know the energy of the Gamma radiation, varies with distance from the source, shielding ....

How much equivalent radiation?

What if you weren't exposed to gamma radiation?

Make a weighting factor to convert all types of radiation into Joule of gamma radiation

Unit

Sievert (Sv) = 1 equivalent J kg^{-1}

rem = Roentgen equivalent man = equiv of 1 rad
100 rem = 1 Sv

Table 7.3 Physiological Effects of a Single Dose of Radiation

Dose (rem)	Dose (Sv)	Likely effect
0–25	0–0.25	No observable effect
25–50	0.25–0.5	White blood cell count decreases slightly
50–100	0.5–1	Significant drop in white blood cell count, lesions
100–200	1–2	Nausea, vomiting, loss of hair
200–500	2–5	Hemorrhaging, ulcers, possible death
>500	>5	Death

Right now you are being exposed to nuclear radiation primarily from

A. radiation coming from the nuclear plants in Japan

B. small amounts of Uranium in the ground

C. radiation from space

D. the person sitting next to you

TABLE 20.7

Typical Radiation Exposures for a Person Living in the United States ($1 \text{ millirem} = 10^{-3}$ rem)

Source	Exposure (millirems/year)
Radon	200
Cosmic radiation	27
From the earth	28
From building materials	3
In human tissues	39
Inhalation of air	5
Total from natural sources	302
X-ray diagnosis	50
Radiotherapy	10
Internal diagnosis/therapy	1
Nuclear power industry	0.2
TV tubes, industrial wastes, etc.	2
Radioactive fallout	4
Total from human activities	67
Total	369

Why is Radon such a problem now?

A. increased Uranium mining

B. it is not, we just know about it

C. better housing insulation

D. more houses with basements

Why is there still radiation?

Given the Earth was formed long ago
and radioactive nuclei decay,
why are there still lots of radioactive isotopes on Earth?

A. because we started with more and they haven't all decayed

B. more are constantly being created in nuclear reactors

C. fall out from atomic bombs and tests

D. radiation from space is constantly generating more

E. more are created in the center of the Earth

Where does radiation come from?

- Unstable radioisotopes
  - Naturally found in environment
  - Made by humans for medical, energy, defense purposes

Fig. 7.19

BACKGROUND RADIATON

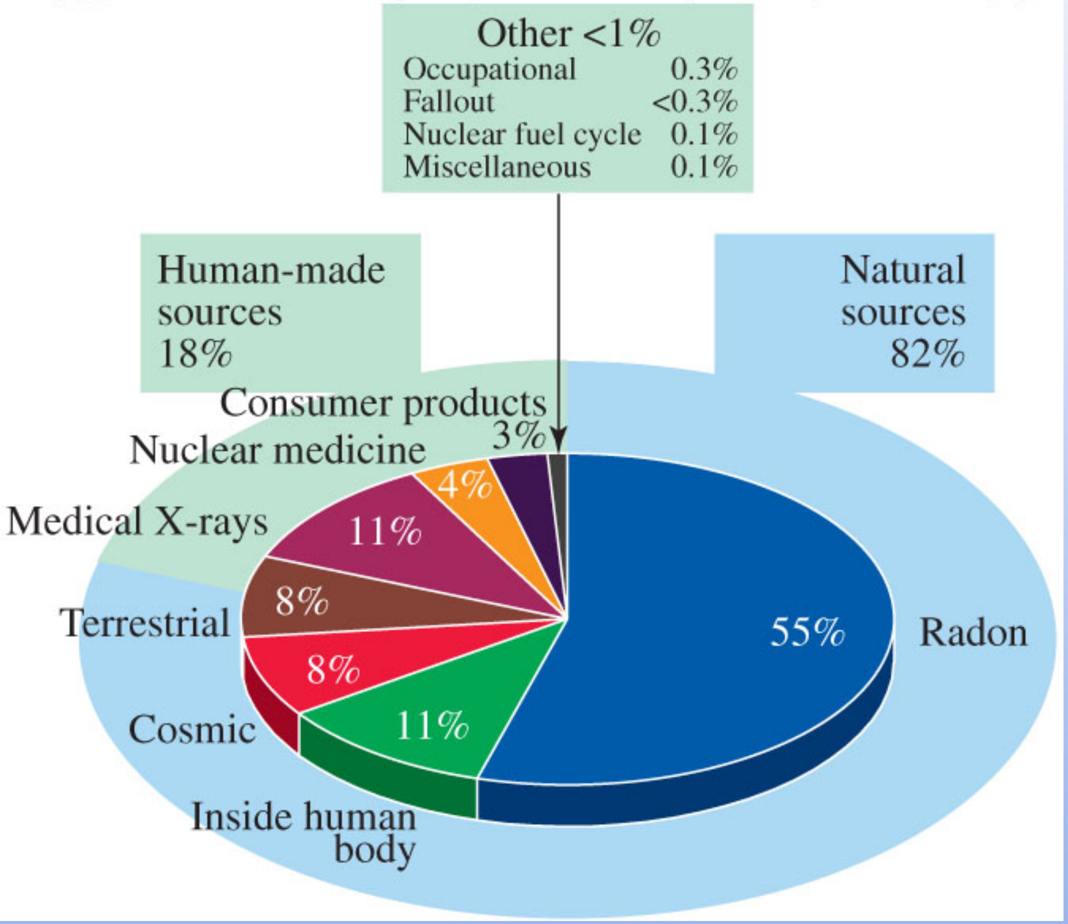


Table 7.3 Annual Radiation Dose (Sample Calculation)*

Sources of Radiation	(μSv/yr)
1. Cosmic radiation	
a. Sea level (U.S. average)	260
b. Additional dose if you are above sea level	
up to 1000 m (3300 ft) add 20 μSv	20
1000 to 2000 m (6600 ft) add 50 μSv	
2000 to 3000 m (9900 ft) add 90 μSv	
3000 to 4000 m (13,200 ft) add 15 μSv	
4000 to 5000 m (16,500 ft) add 21 μSv	
2. Building material(s) used in your dwelling	
Stone, brick or concrete add 70 μSv	
Wood or other add 20 μSv	20
3. Rocks and soil	460
4. Food, water, and air (K and Rn)	2400
5. Fallout from nuclear weapons testing	10
6. Medical and dental X-rays	
a. Chest X-ray, add 100 μSv each	0
b. Gastrointestinal tract X-ray, add 5000 μSv each	0
c. Dental X-rays, add 100 μSv each	100
7. Airplane travel	
5-hour flight at 30,000 feet, add 30 μSv/flight	300
8. Other	
a. Live within 50 miles of a nuclear plant, add 0.09 μSv	0.09
b. Live within 50 miles of a coal-fired power plant, add 0.3 μSv	0.3
c. Use a computer terminal, add 1 μSv	1
d. Watch TV, add 10 μSv	10
e. Smoke one pack of cigarettes/day, add 10,000 μSv	0
Total Annual Radiation Dose	**3581**
U.S. annual average = 3600 μSv	

*Sample calculation is for an adult nonsmoker living in the Midwest.

Sources: U.S. Environmental Protection Agency, American Nuclear Society.

Most abundant and troublesome radioisotopes produced in fission reactions.

Cs-137 - ½ life 30 years, beta emitter

I-131 - ½ life 8 days, beta emitter

Sr-9 – ½ life 29 years, beta emitter

Sr-90

Radioactive Decay and Dating

We can use isotopic abundance as a means of determining the age of some substances

How is this possible if they are all decaying all the time?

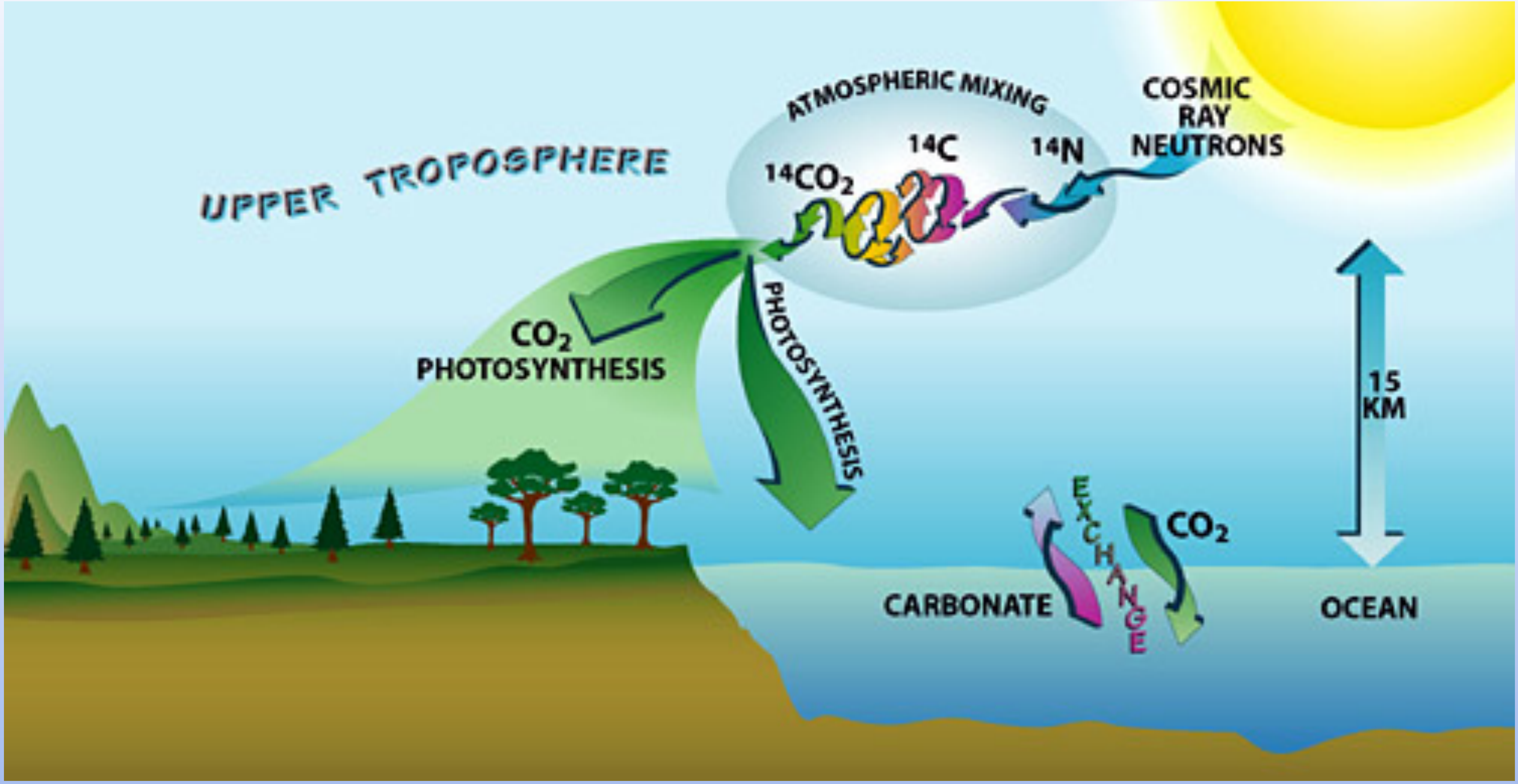
Some compounds are constantly regenerated

^{14}C is a radioactive isotope of carbon

The amount of ^{14}C in a substance relative to the amount of ^{12}C can be used to determine its age!

How is this possible since ^{14}C is constantly decaying won't everything have the same ratio?

The amount of ^{14}C in the atmosphere is essentially constant!


UPPER TROPOSPHERE
ATMOSPHERIC MIXING
$^{14}CO_2$
^{14}C
^{14}N
COSMIC RAY NEUTRONS
CO_2 PHOTOSYNTHESIS
PHOTOSYNTHESIS
15 KM
EXCHANGE
CO_2
CARBONATE
OCEAN

http://en.wikipedia.org/wiki/Carbon-14

Problems with carbon dating

The ^{14}C concentration is not actually constant

The ^{14}C concentration can vary by location

Nuclear testing has totally screwed this up for people 10,000 years from now

^{14}C half life is ~5,000 years. So it is useful for the 1000's of years type dating

Medical Uses of Radiation

Radiation is used to treat cancer because

A. it only harms cancer cells

B. it can effectively kill all living cells

C. it kills all cells, but mostly only cancer cells

D. it isn't used to treat cancer it causes cancer

Treating Thyroid Cancer

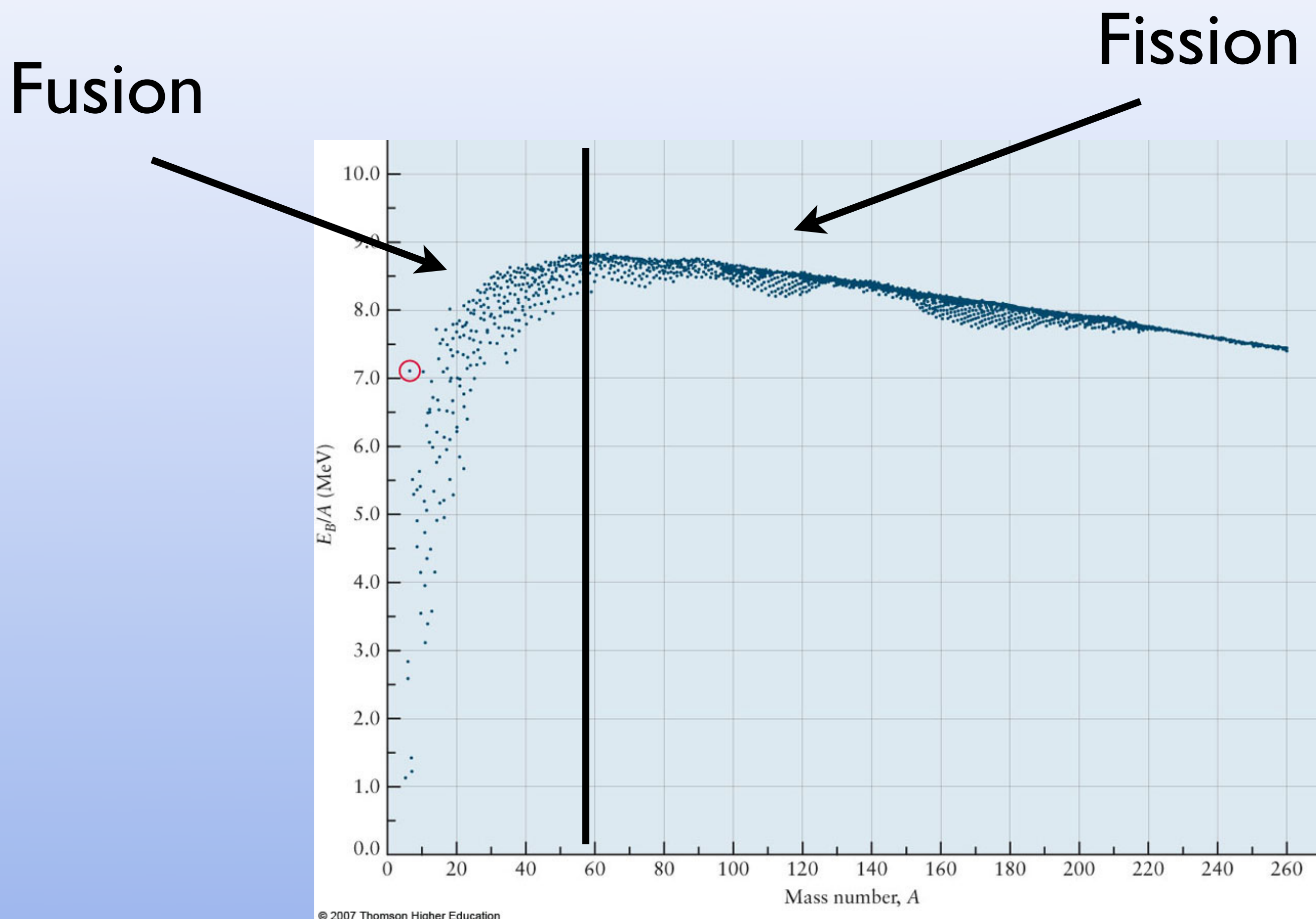
I-131 accumulates in the thyroid

Treating Bone Cancer

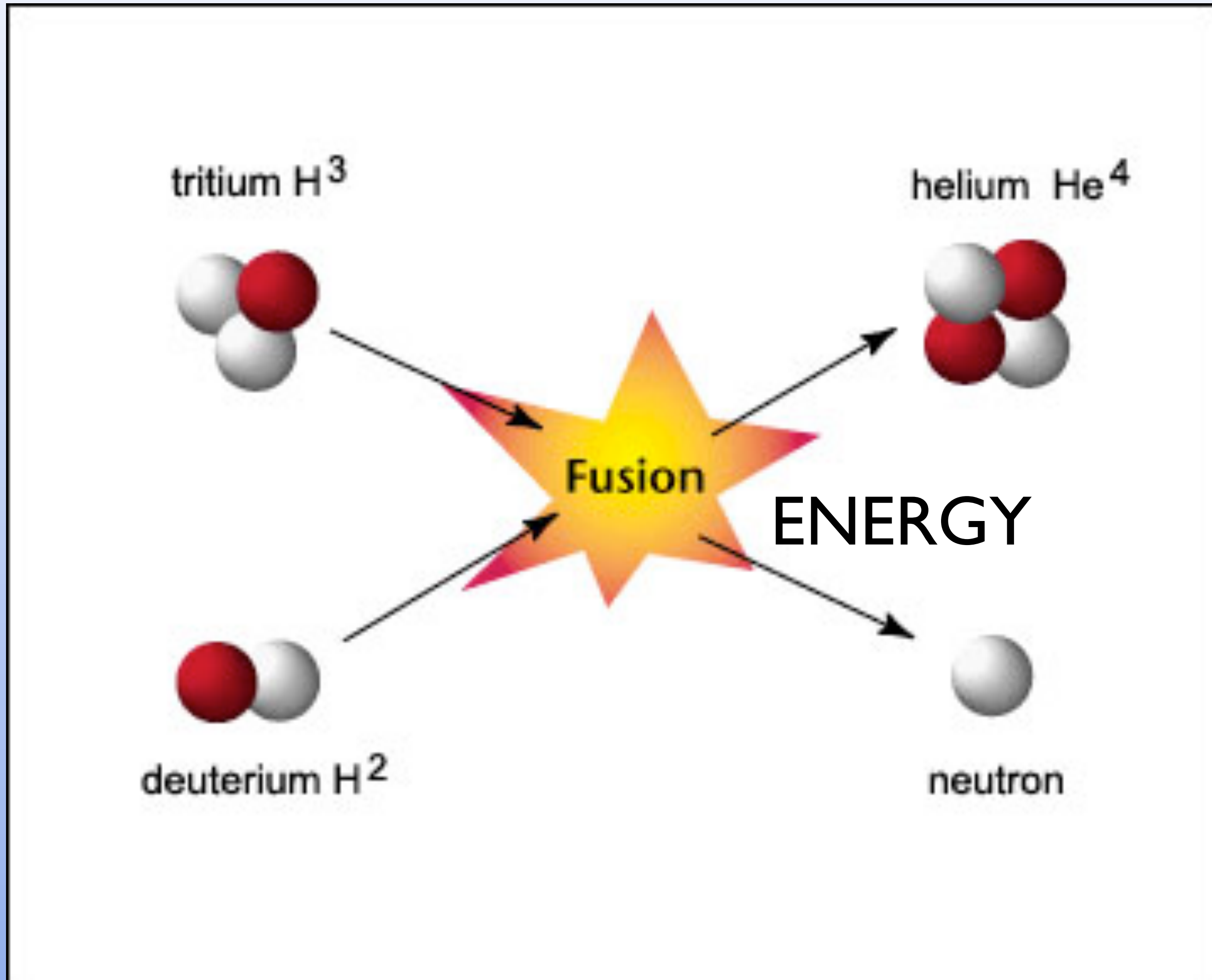
Sr builds up in the bones

Sr-90 very bad 1/2 life of 29 years
Sr-89 1/2 life of 50 days

Nuclear Power



What's so great about Fusion?



What's so great about Fusion?

Abundant starting materials

Much less generation of radioactive "waste"

Why are we using it today?

Why aren't we using Fusion?

A. there have been no man-made nuclear fusion reactions

B. there have been reactions but we can't contain them

C. there have been reactions but only very very small ones

D. B & C

Fusion

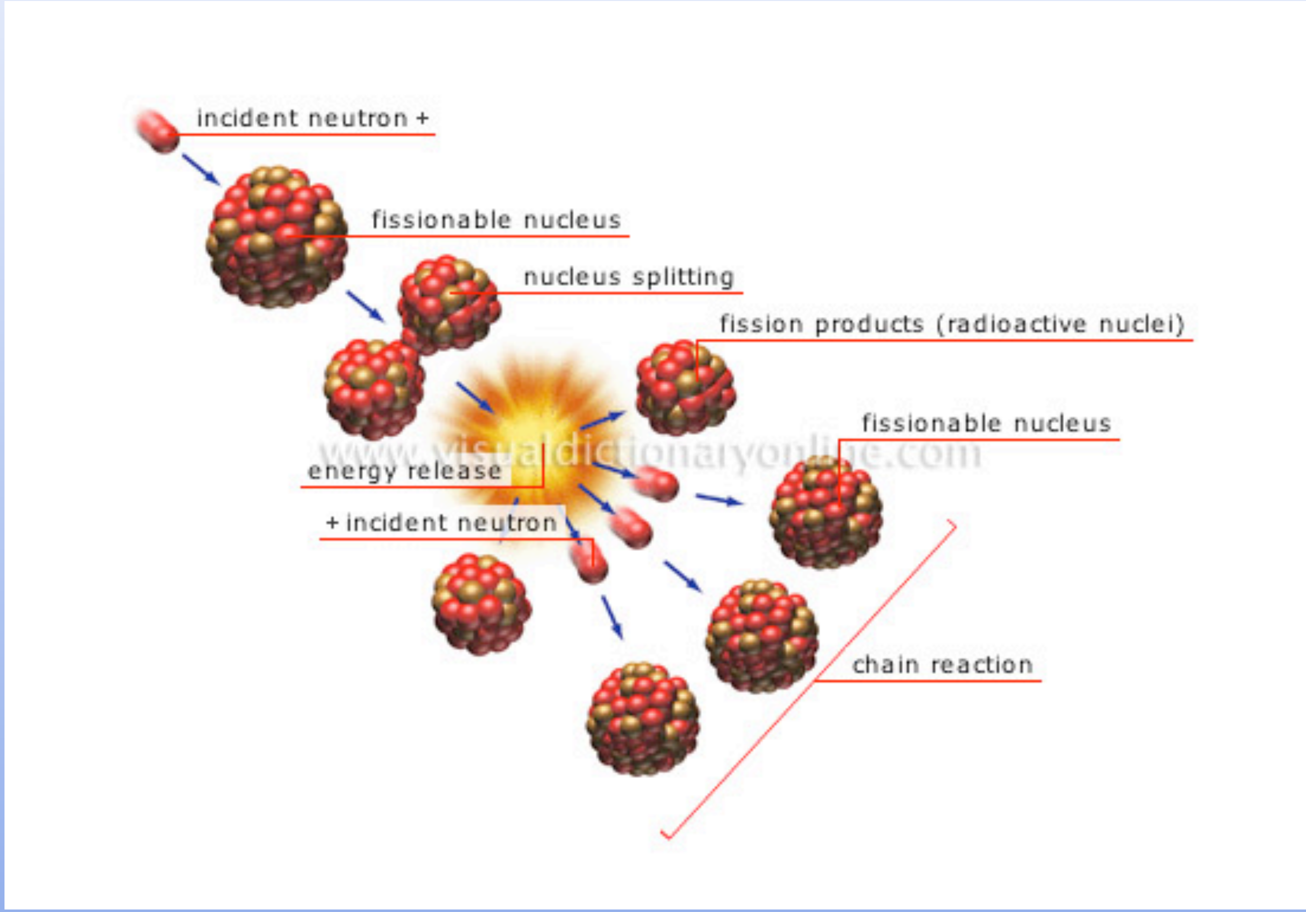
Requires "shoving" nuclei together

Very difficult to do

High temperature and High pressure
No current scheme to start and maintain

Fission

Why is fission easy?

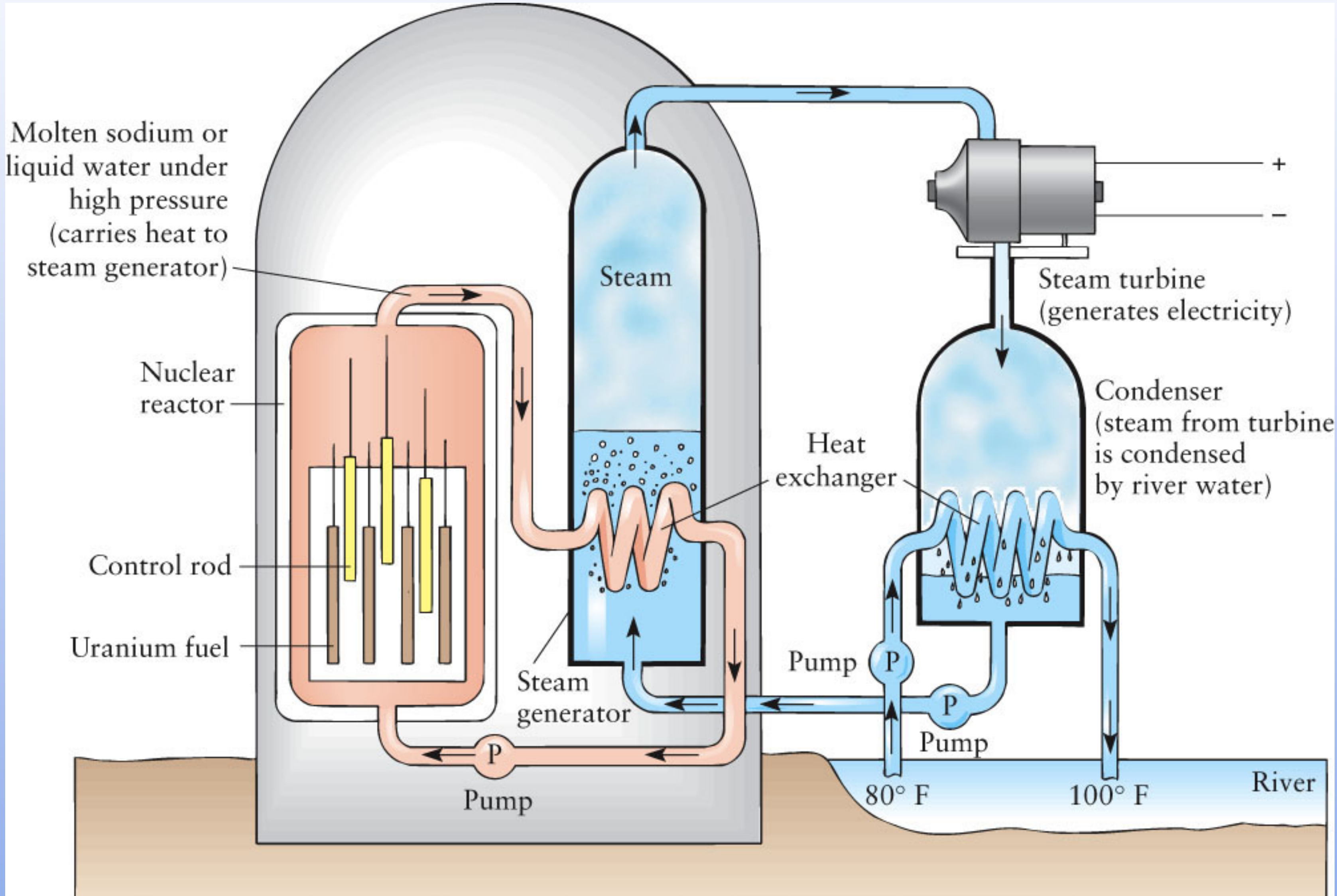


2nd order reaction

Need high concentration of neutrons

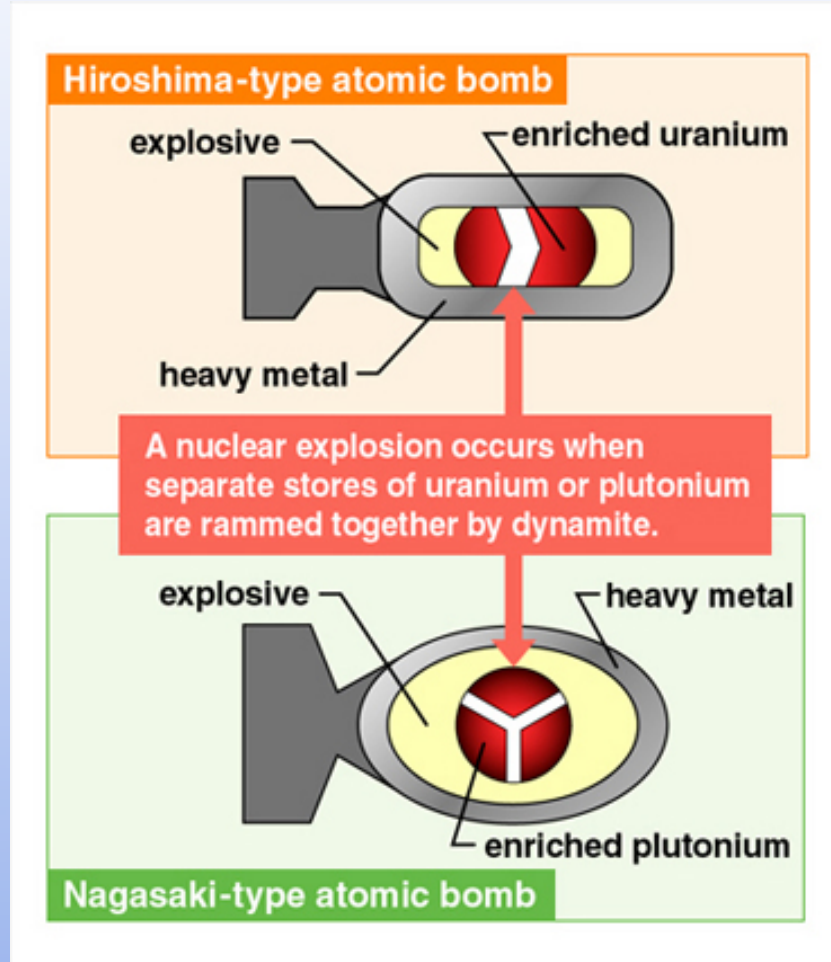
high concentration of “fissionable” material

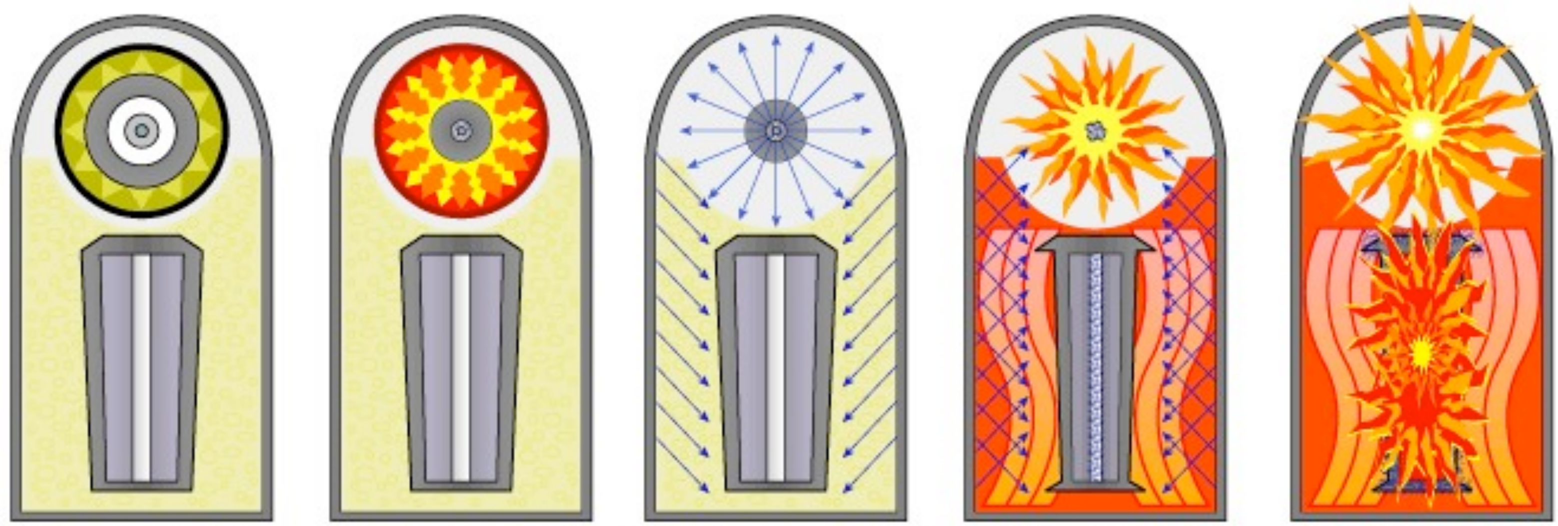
All nuclear reaction are first order?



Fuels for bombs

- U-235
- Pu-239
- Hydrogen bomb
- Dirty Bomb


Hiroshima-type atomic bomb
explosive
enriched uranium
heavy metal
A nuclear explosion occurs when separate stores of uranium or plutonium are rammed together by dynamite.
explosive
heavy metal
enriched plutonium
Nagasaki-type atomic bomb



1. Warhead before firing; primary (fission bomb) at top, secondary (fusion fuel) at bottom, all suspended in polystyrene foam.

2. HE fires in primary, compressing plutonium core into supercriticality and beginning a fission reaction.

3. Fissioning primary emits X-rays which reflect along the inside of the casing, irradiating the polystyrene foam.

4. Polystyrene foam becomes plasma, compressing secondary, and plutonium sparkplug begins to fission.

5. Compressed and heated, lithium-6 deuteride fuel begins fusion reaction, neutron flux causes tamper to fission. A fireball is starting to form...