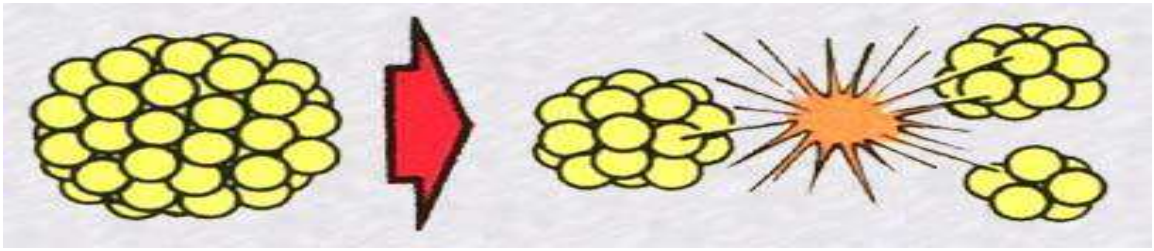
NOTES: 25.3 –
Nuclear Fission & Fusion

Nuclear Fission:

- The splitting of a heavy nucleus into lighter nuclei

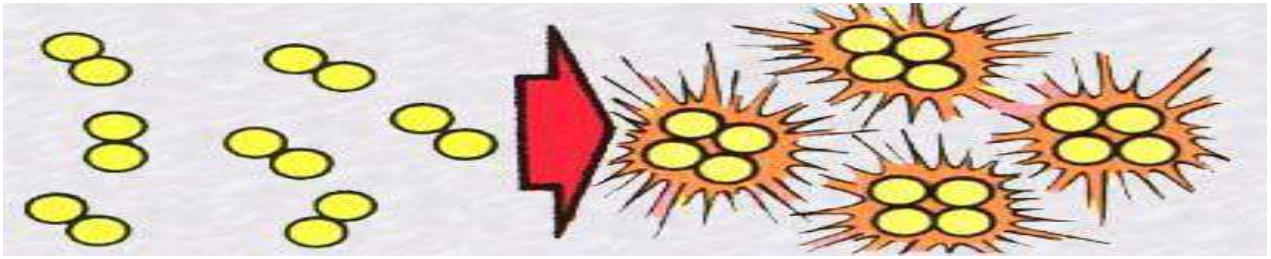


FISSION: a heavy nucleus splits into 2 lighter nuclei

- some elements undergo fission spontaneously
- some elements can be induced to undergo fission when bombarded with other particles (e.g. neutrons)

Nuclear Fusion:

- the combination of light nuclei to produce a heavier nucleus



FUSION: 2 nuclei combine to form a heavier nucleus

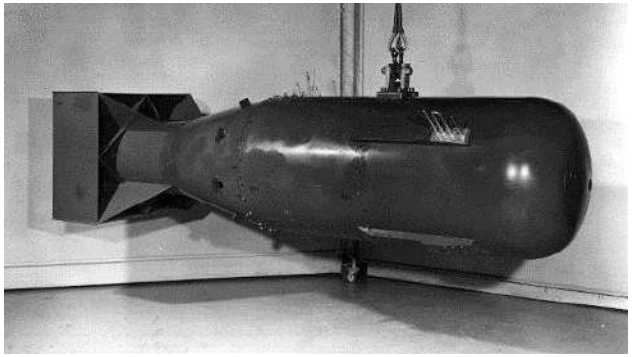
- the sun is a tremendous fusion reaction; the major fusion reaction in the sun is thought to be:

$$ {}^{2}_{1}\mathrm{H} + {}^{3}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n} + \text{energy!} $$

- both fission & fusion release large amounts of energy (fusion more than fission)

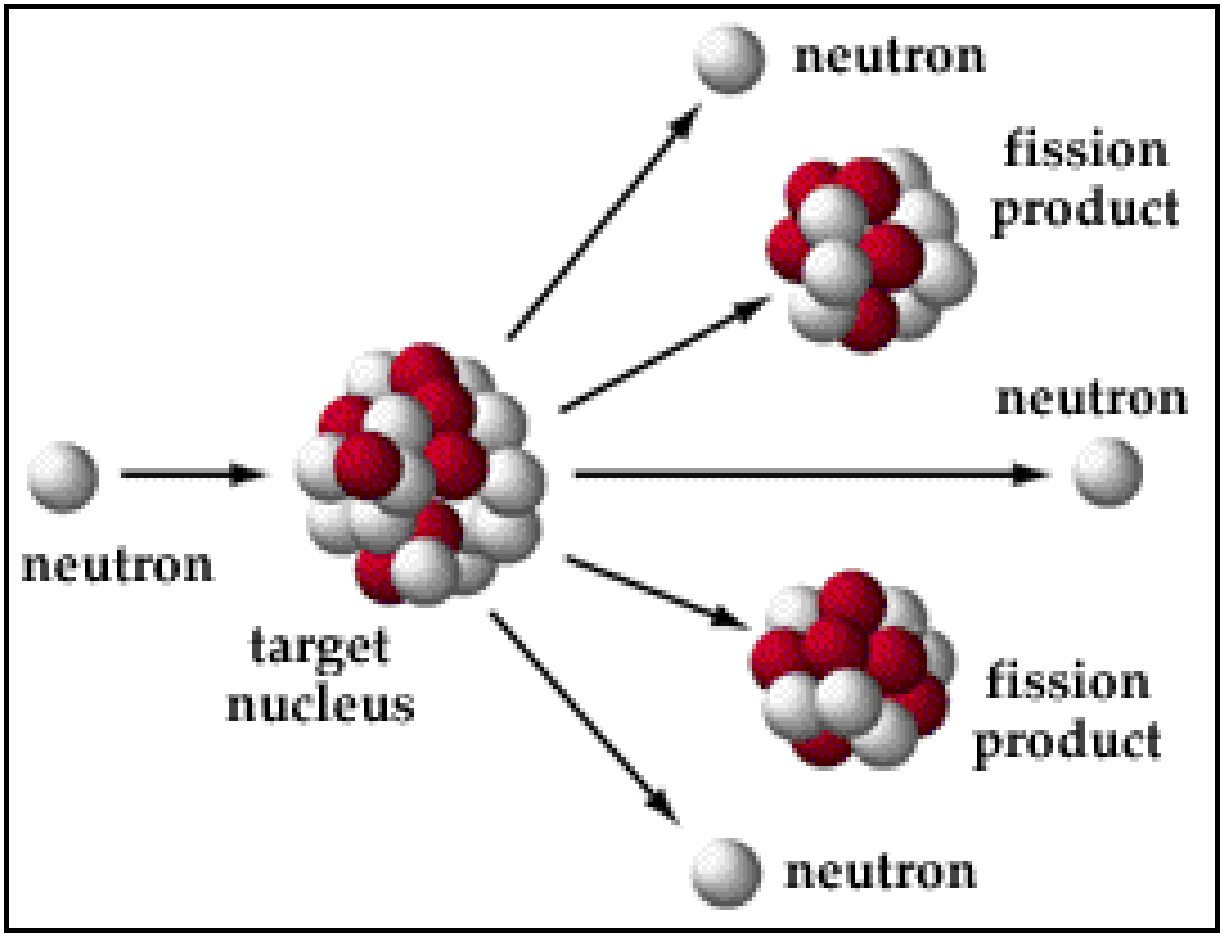
Uses / Applications of FISSION:

The Atomic Bomb (FISSION)

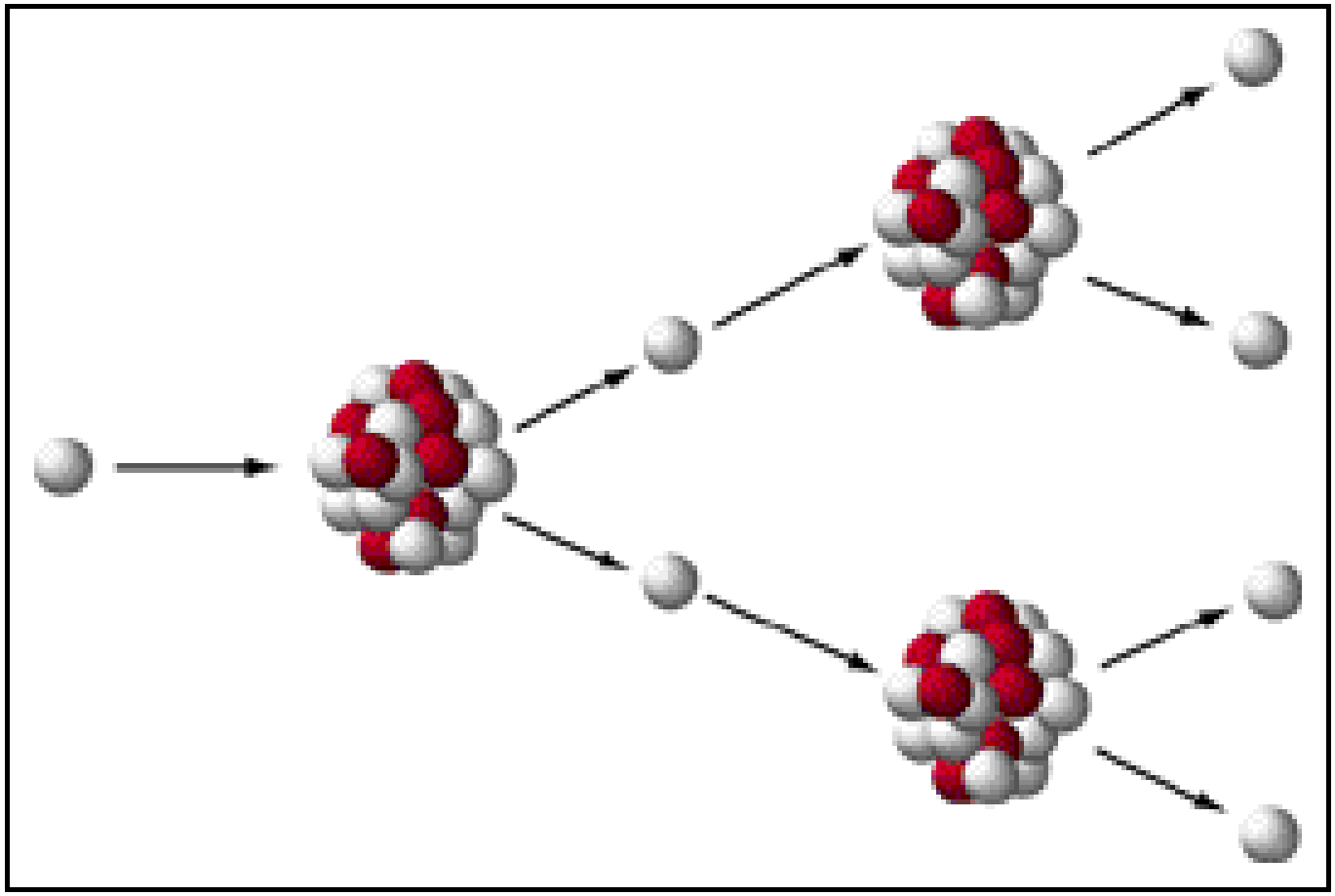


- when the nucleus of U-235 splits, 2 isotopes are formed, plus neutrons are emitted
- these neutrons collide with other U-235 atoms, causing them to undergo fission; they release neutrons, and so on…
- **The result - CHAIN REACTION!!**

FISSION:

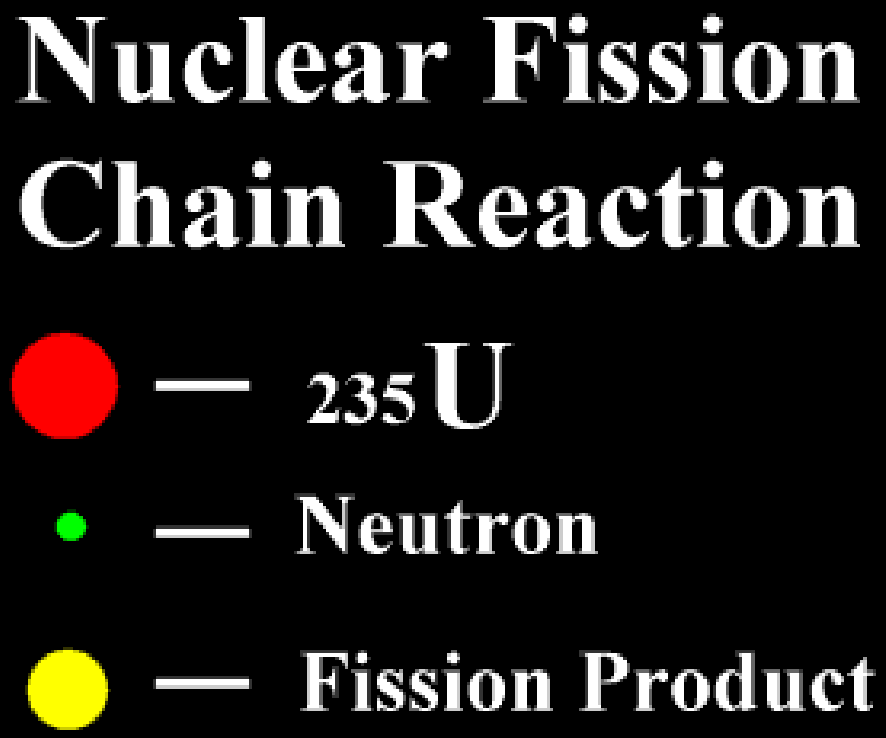

neutron
fission product
neutron
neutron
target nucleus
fission product
neutron

FISSION / CHAIN REACTION!!!



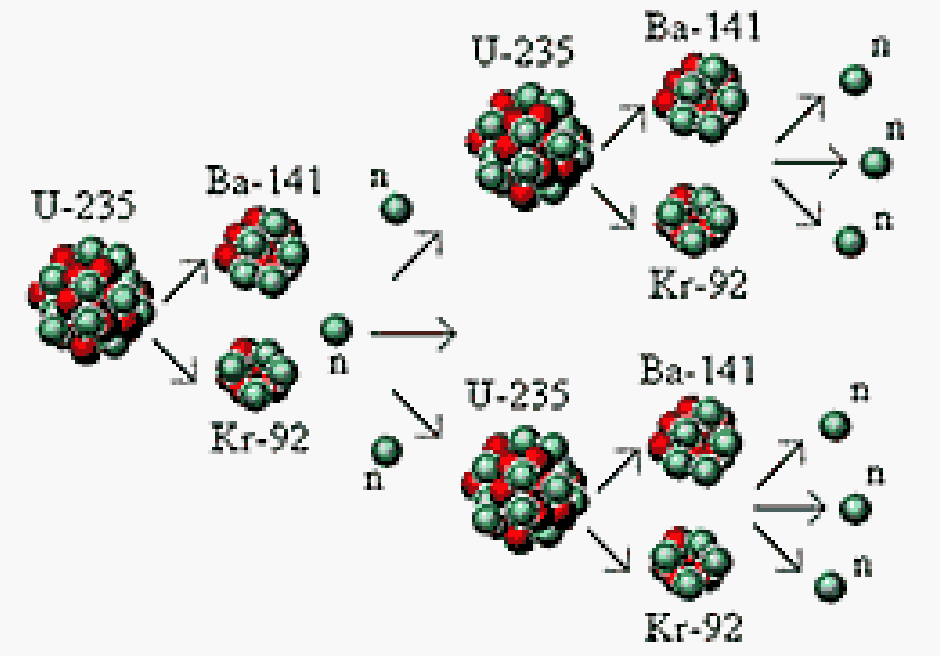
The Atomic Bomb (FISSION)

The Atomic Bomb (FISSION)



CRITICAL MASS:

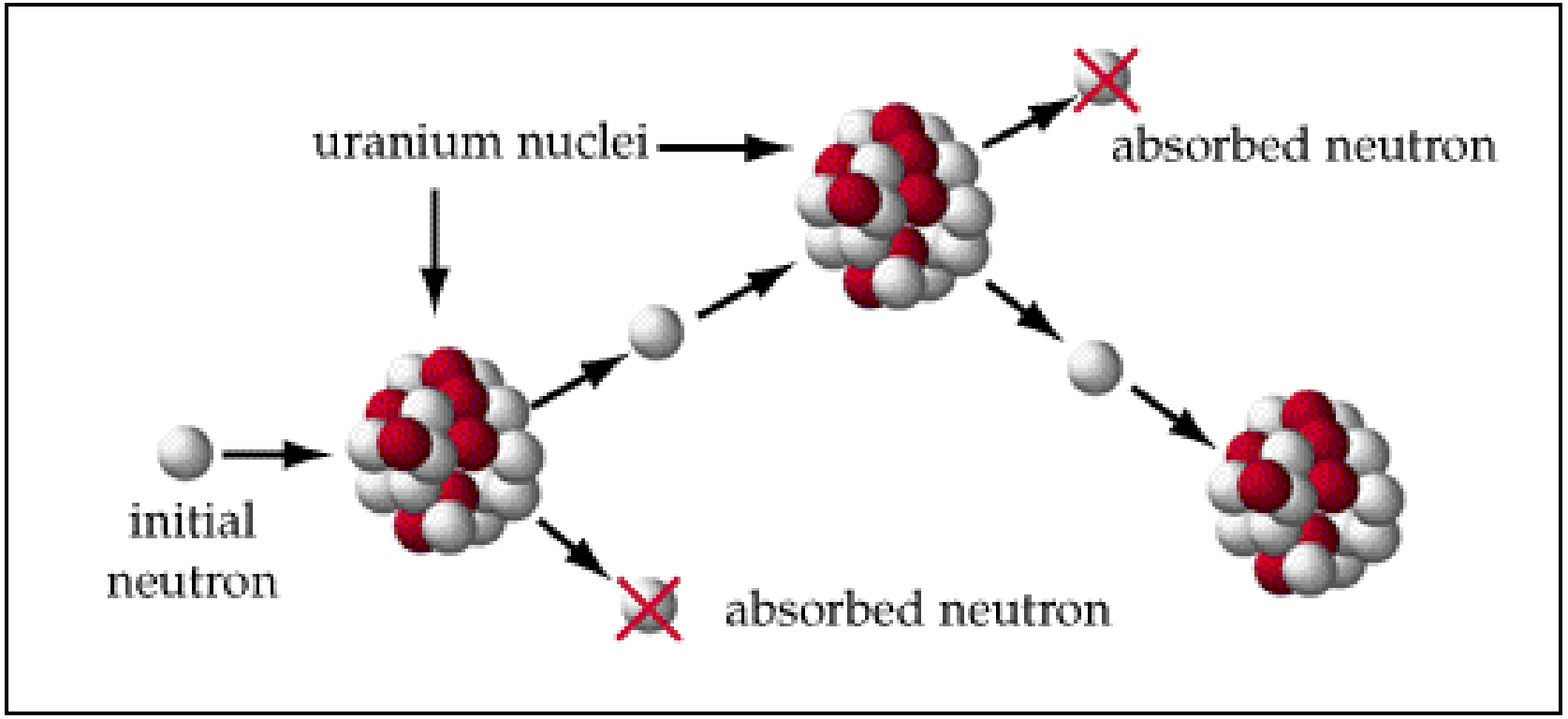
- The minimum mass of fissionable material that must be used to sustain a chain reaction



Two types of bombs (but both use FISSION)…

- Little Boy: U-235 (Hiroshima)
- Fat Man: Pu-239 (Nagasaki)

Nuclear Reactors (controlled FISSION)



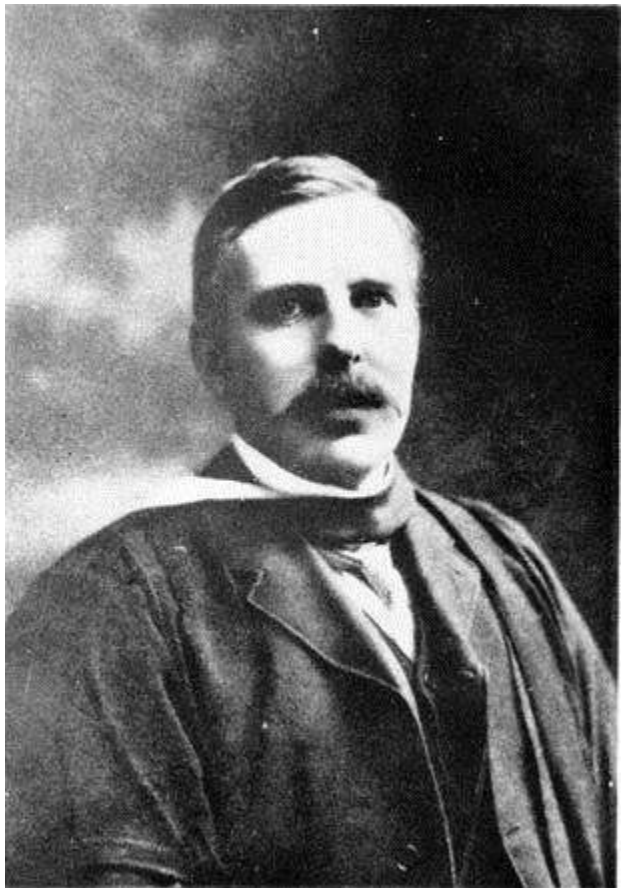
Nuclear Reactors (controlled FISSION):

- use subcritical masses of fissionable material
- **CORE**: contains fuel pins made of U-235; interspersed among the pins are **control rods**
- control rods: absorb neutrons
  - -pull rods out of core: fission increases
  - -push rods back into the core: fission decreases
- ***Safety feature***: *if power is lost, rods will automatically fall into the core and shut the reaction down.*

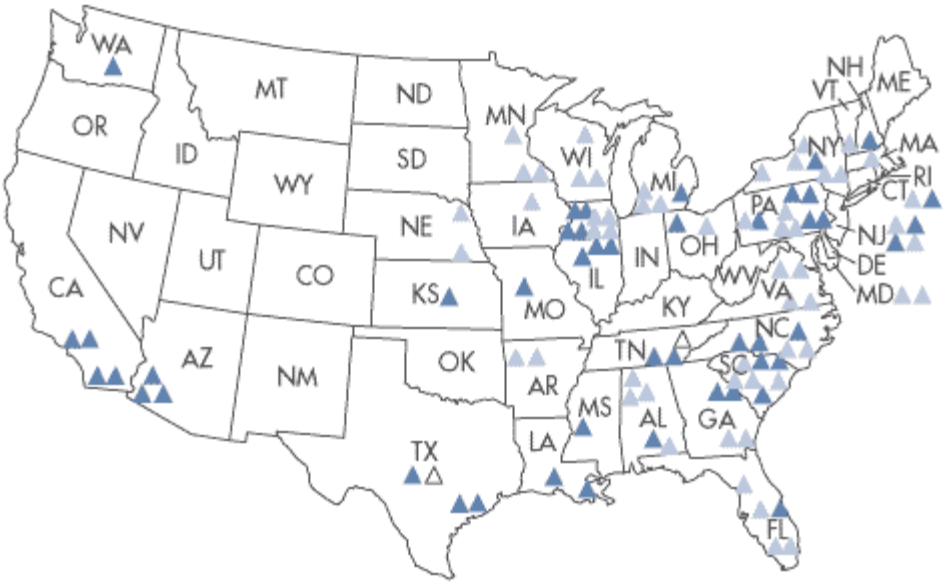
Nuclear Reactors (FISSION)

“The energy produced by breaking down the atom is a very poor kind of thing. Anyone who expects a source of power from the transformation of these atoms is talking moonshine.”

Ernest Rutherford



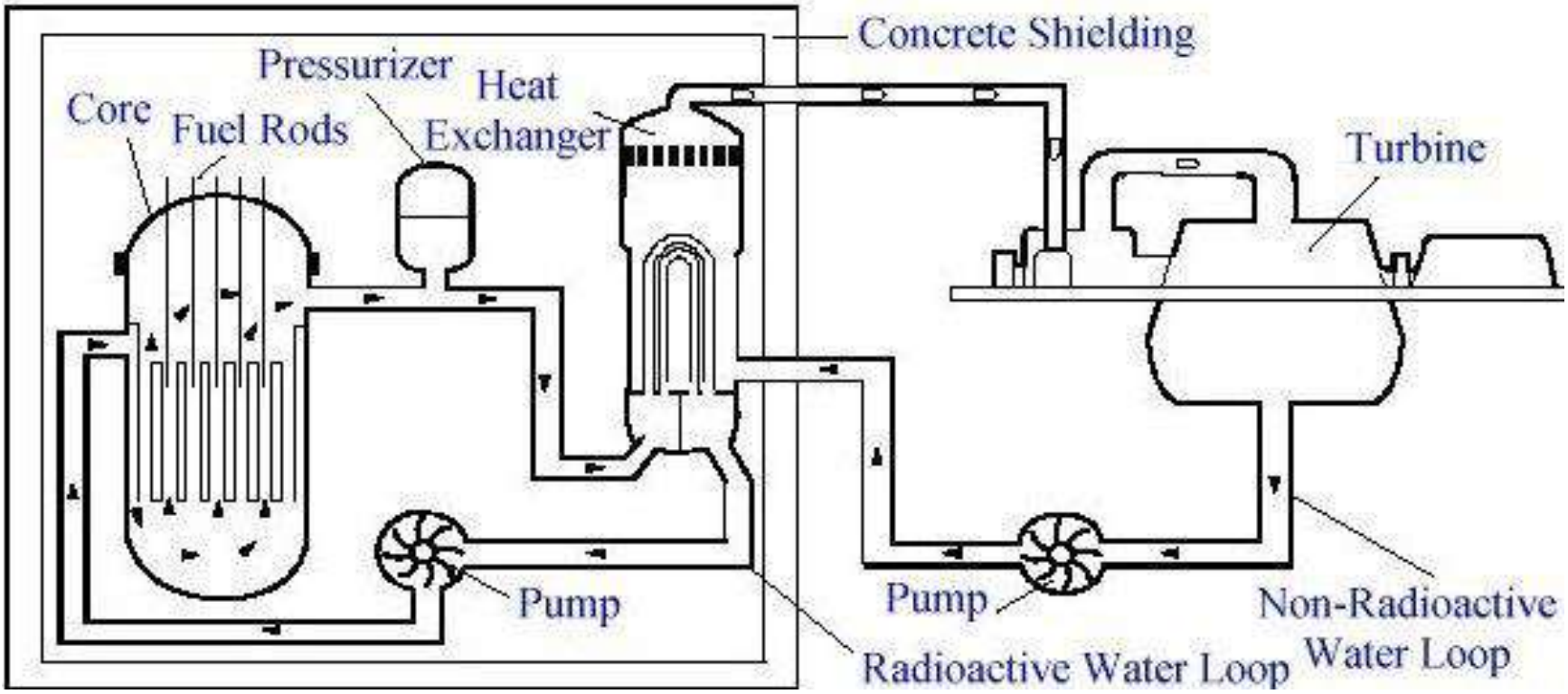
Nuclear Reactors (FISSION)

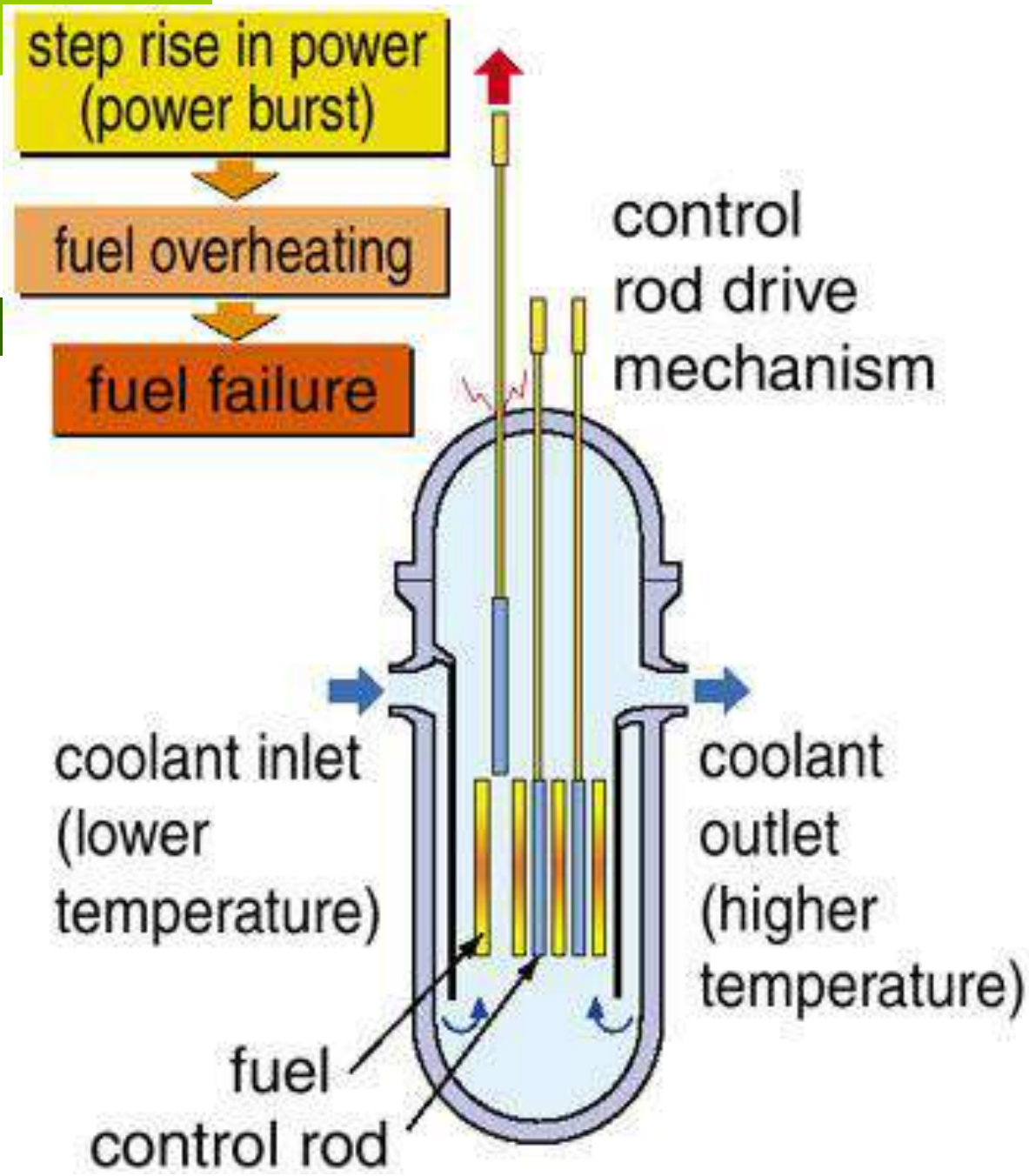


YEARS OF COMMERCIAL OPERATION	NUMBER OF REACTORS	AVERAGE CAPACITY (MDC)
△ 0–9	2	1134
▲ 10–19	47	1092
▲ 20–29	55	779

Note: There are no commercial reactors in Alaska or Hawaii. Calculated data as of 12/00.

Nuclear Power Plants



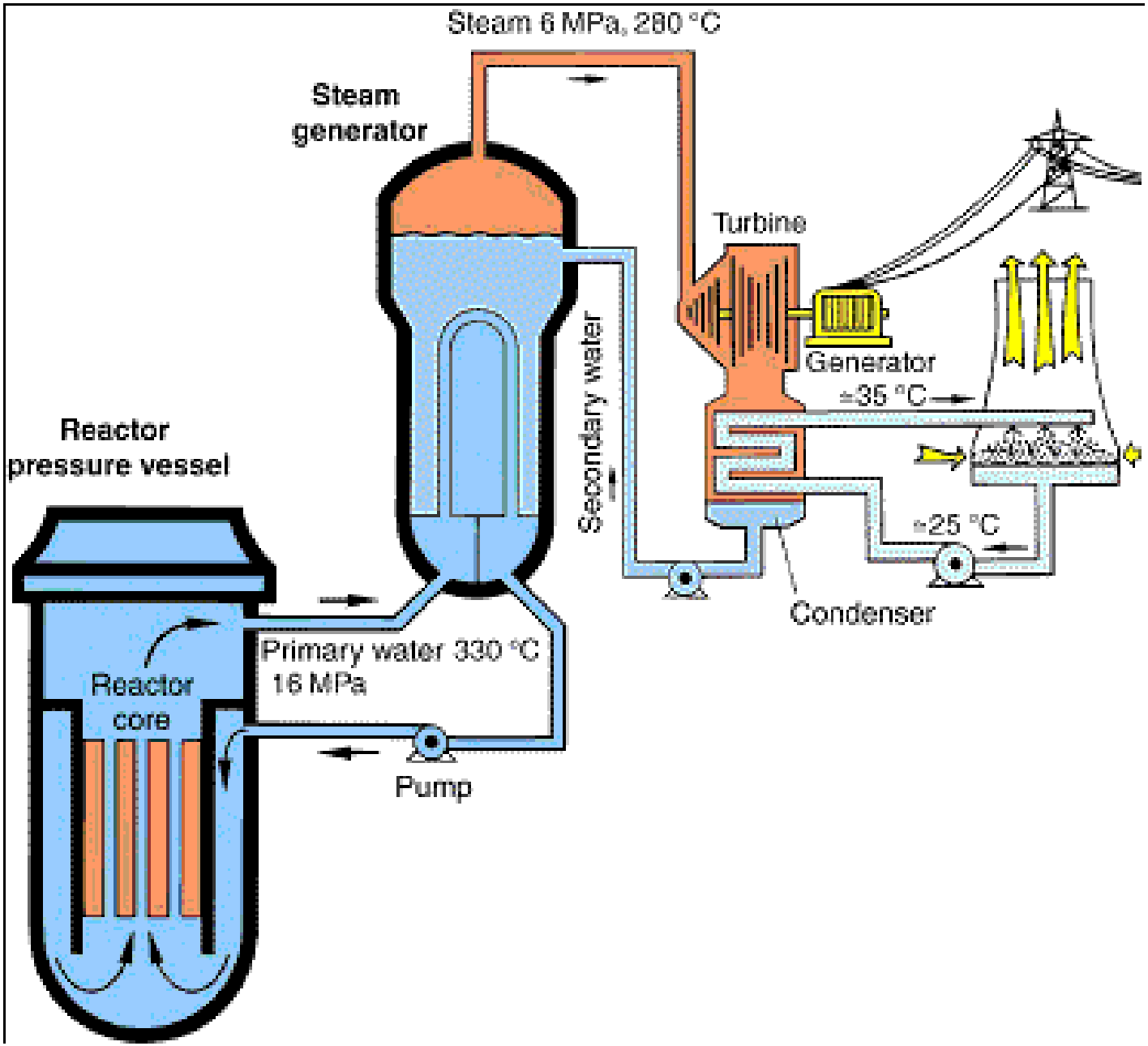

step rise in power
(power burst)
fuel overheating
fuel failure
control
rod drive
mechanism
coolant inlet
(lower
temperature)
coolant
outlet
(higher
temperature)
fuel
control rod

Nuclear Power Plants

Nuclear Power Plants

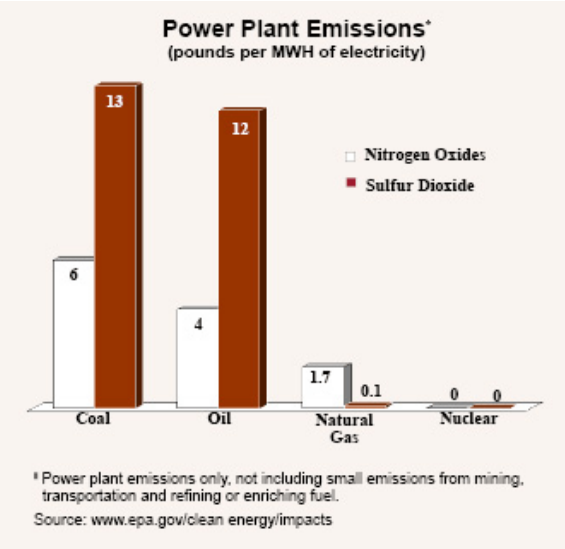
TO GENERATE ELECTRICITY:

1) Fission heats up water in vessel and heat is carried away.
2) This heat is used to heat up water in a second system, which turns into steam.
3) Steam turns turbine of a generator.
4) Generator makes electricity.


Steam 6 MPa, 280 °C
Steam generator
Turbine
Generator
≈35 °C
Secondary water
Reactor pressure vessel
≈25 °C
Condenser
Primary water 330 °C
16 MPa
Reactor core
Pump

PROS OF NUCLEAR ENERGY:

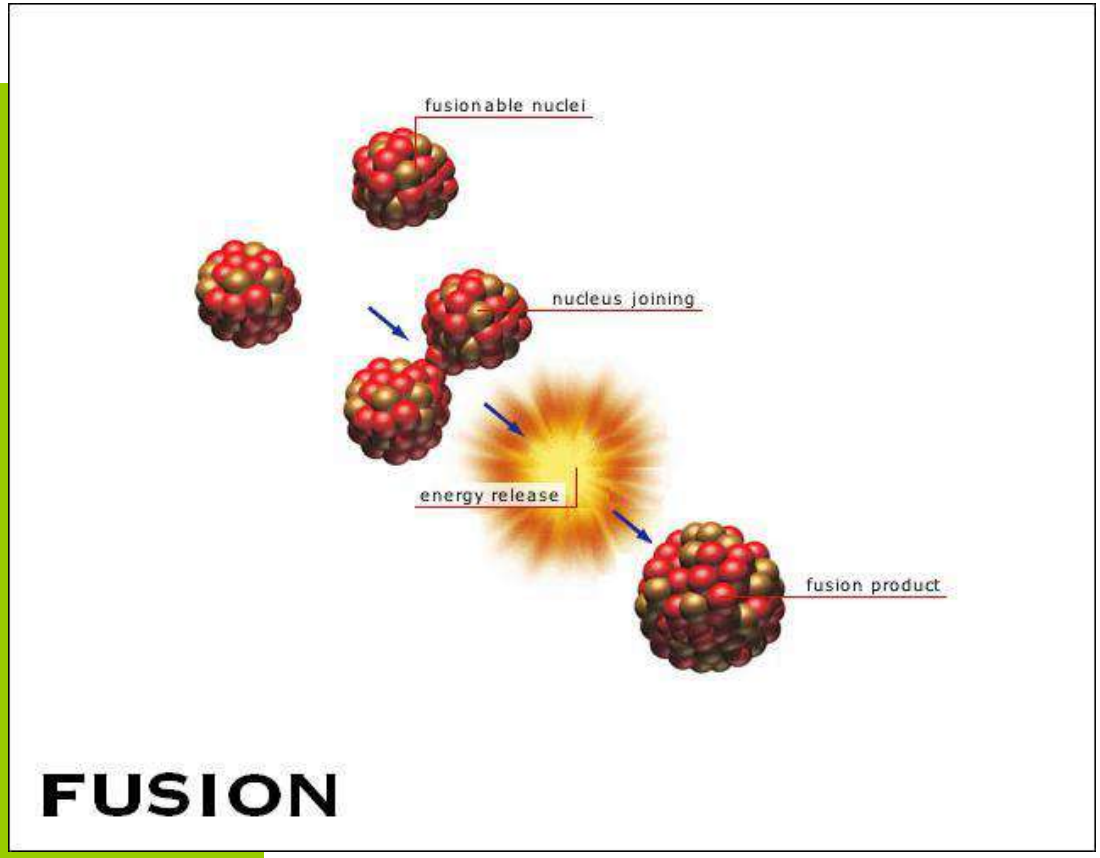
- no air pollution
- enormous amt. of energy released
- alternative to using our rapidly decreasing fossil fuels



CONS OF NUCLEAR ENERGY:

- containers for waste products may erode or break
- thermal pollution (heated water returned to rivers, etc.)
- potential theft of fuel (Pt-239) for use in weapons

What about applications / uses of FUSION?



Controlled Nuclear FUSION

- **PROS**:

  -a very abundant supply of energy world wide.

  -environmentally clean

  -no creation of weapon materials

  -no chance of runaway reactions leading to accidents

- **CONS**:

  -it doesn’t work; at least not yet…

Nuclear Fusion:

"Every time you look up at the sky, every one of those points of light is a reminder that fusion power is extractable from hydrogen and other light elements, and it is an everyday reality throughout the Milky Way Galaxy."

Carl Sagan, Spitzer Lecture, October 1991

Nuclear Fusion:

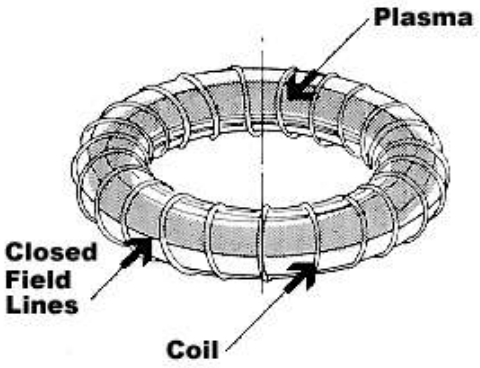
- **Obstacles**…

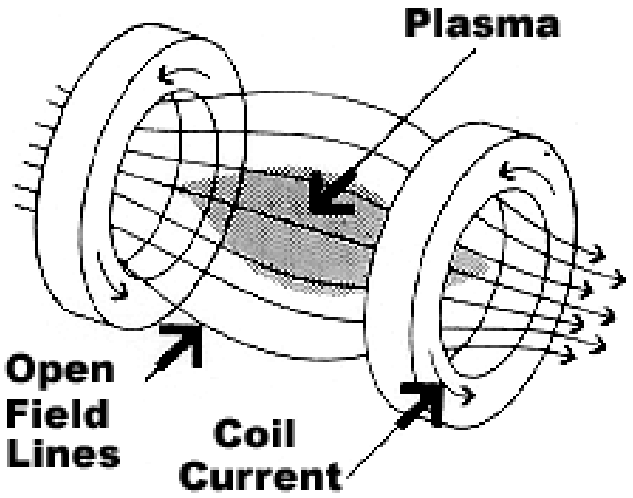
  -**HOT!** – plasma at least 100 million °C

  -high density plasma

  -containment of plasma

  -confinement time





NOTES: 25.4 –
Radiation in the “real” world:

Detecting Radiation:

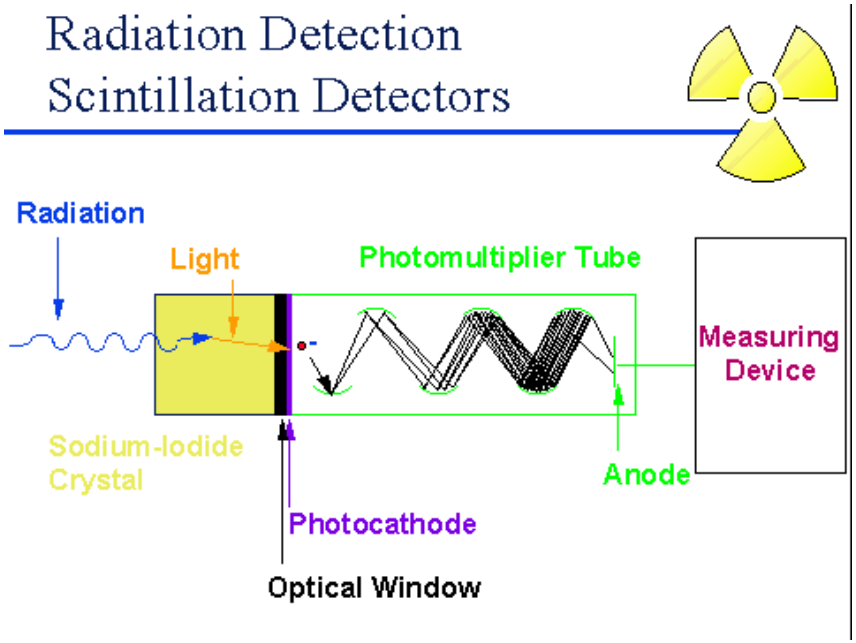
- radiation cannot be seen, heard, felt, or smelled…
- therefore, warning signs and radiation-detection instruments must be used to alert people to the presence of radiation

Geiger Counter:

- detects beta radiation
- radiation enters the tube and ionizes the gas inside
- the free electrons that are produced conduct electricity
- the bursts of electric current cause audible “clicks”

Scintillation Counter:

- uses a special coating that lights up when radiation hits it
- similar to a TV screen



Film Badge:

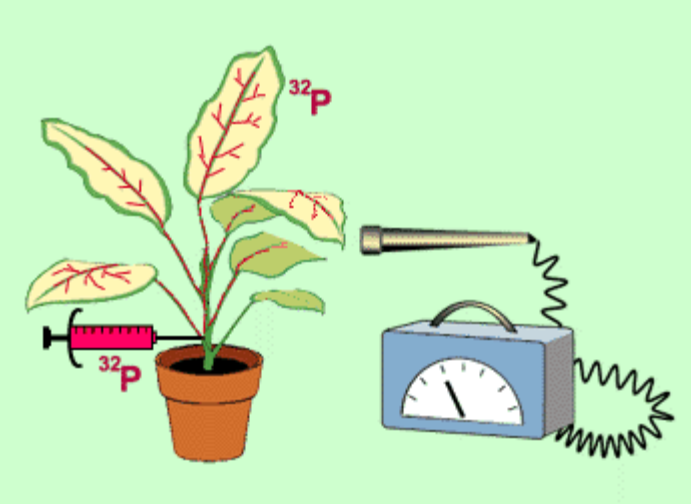
- used by people who work near radiation sources;
- contains several layers of photographic film;
- periodically, the film is removed and developed

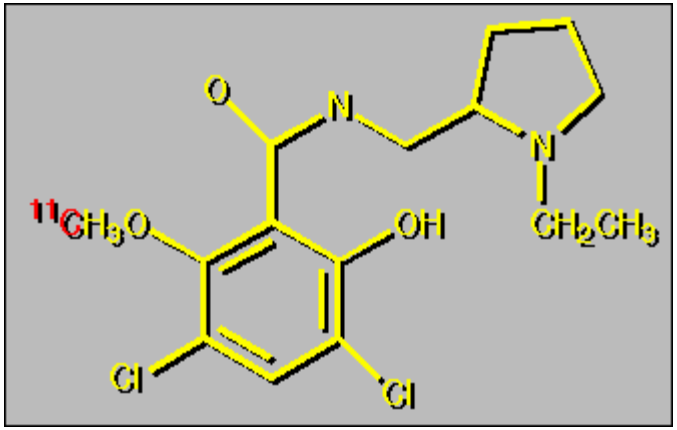
Using Radiation – TRACERS:

- one reactant in a reaction is “labeled” with a radioactive isotope;
- after the reaction is complete, the radiation of the product is measured;
- helps chemists study and understand how particular reactions work.

Using Radiation – TRACERS:

- can be used to test the effects of chemicals in agriculture or in the environment



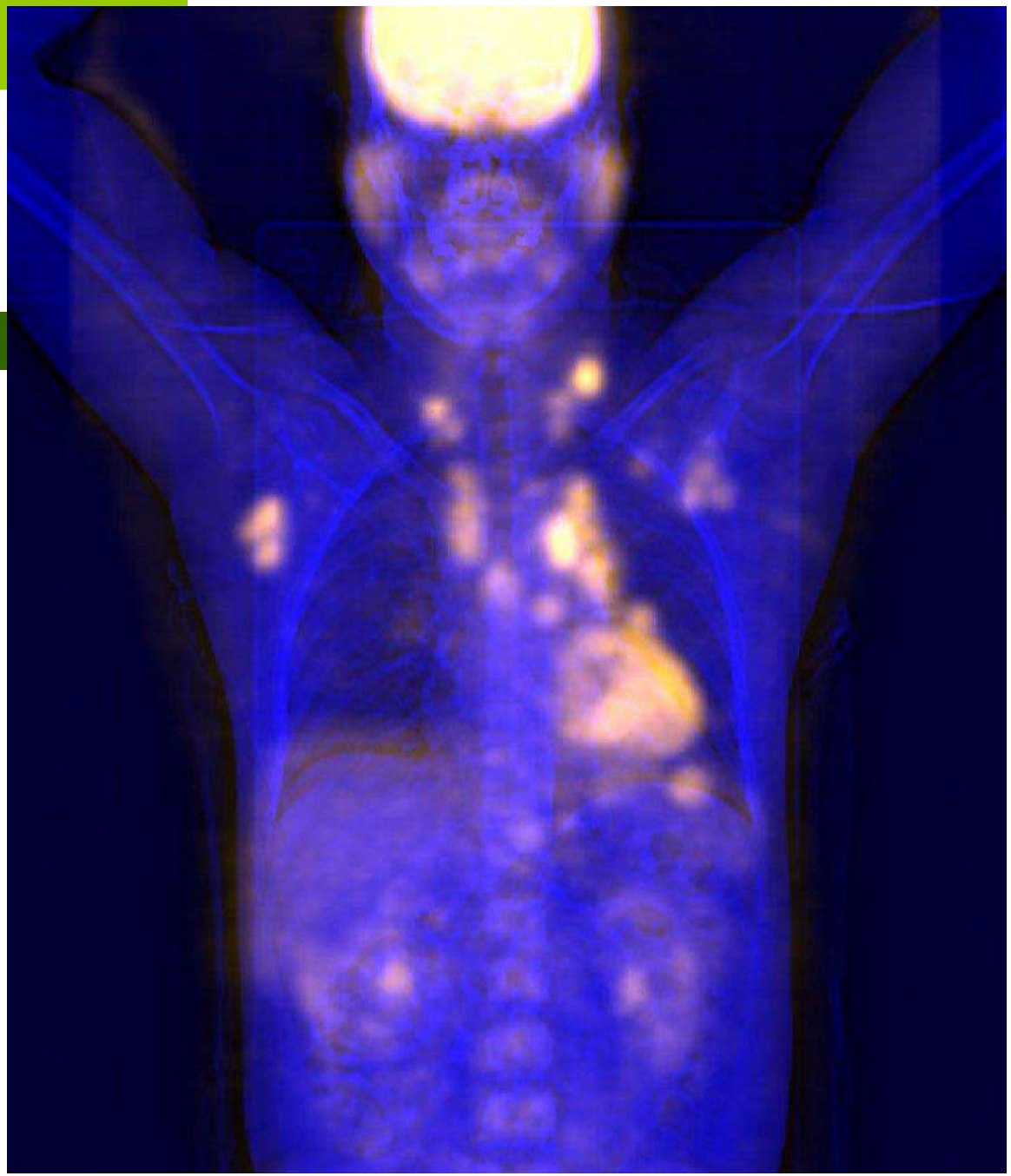


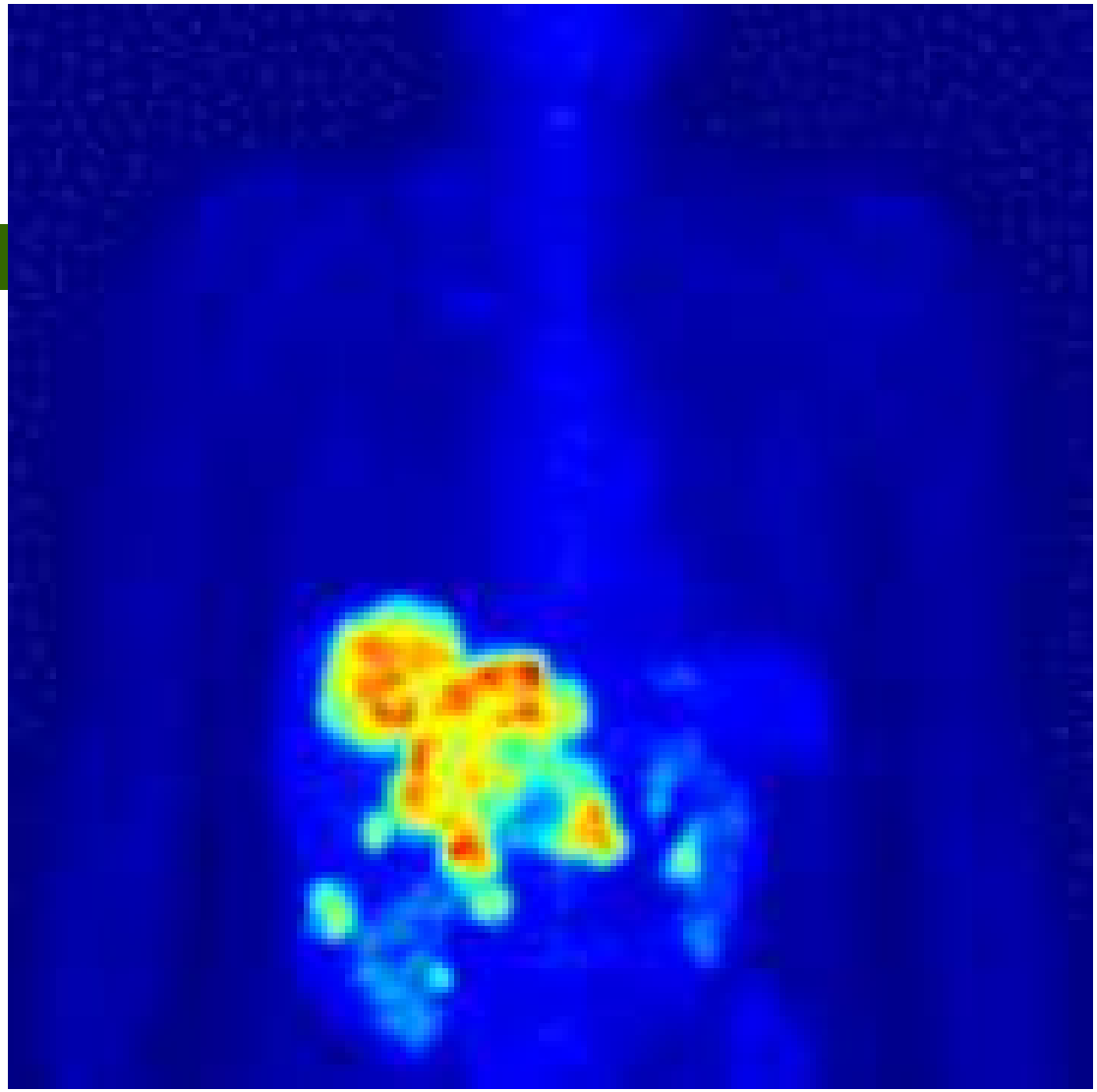
Using Radiation – MEDICINE:

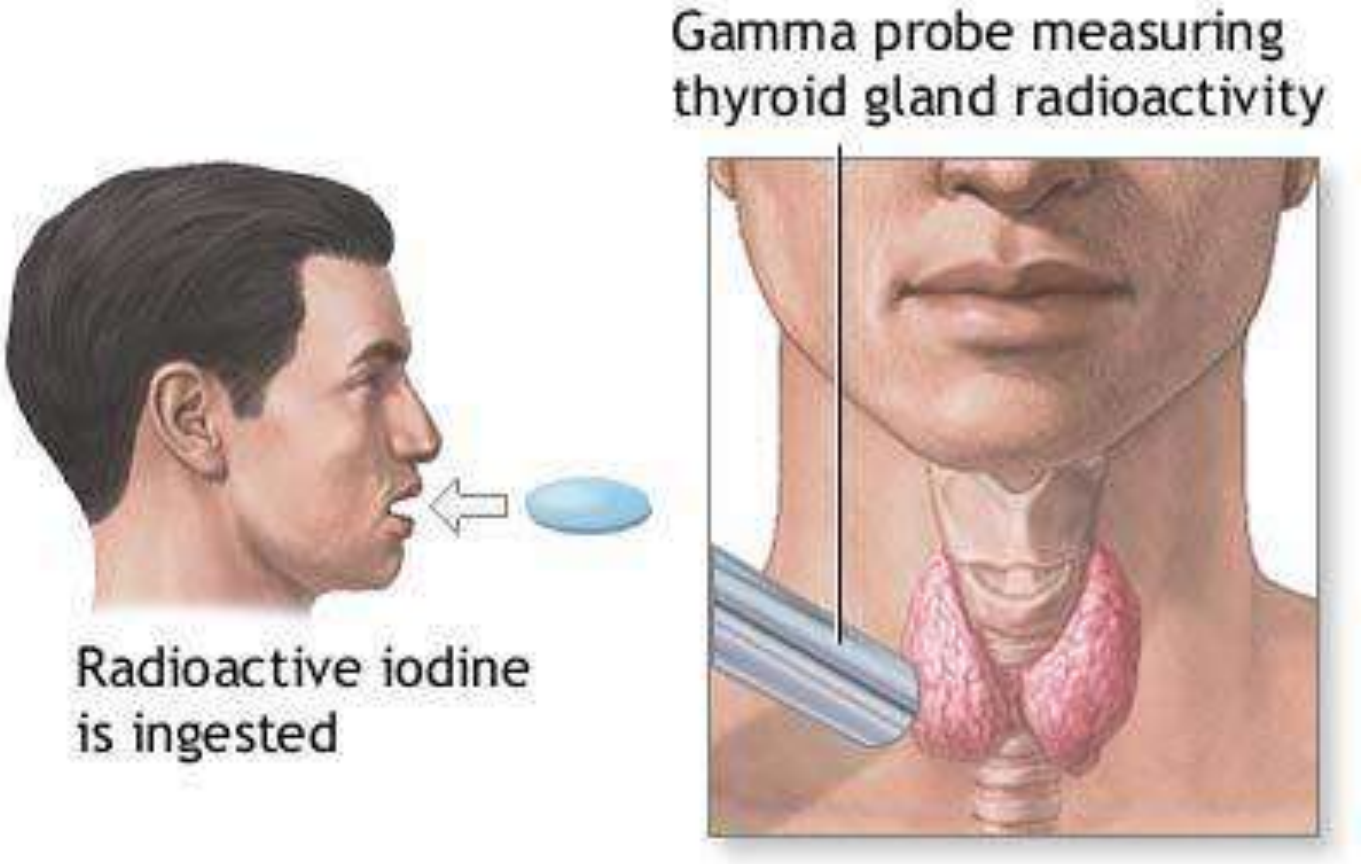
- patients are given a radioactive isotope and then scanned to detect a particular body function;
- **EXAMPLE**:

  -iodine-131 is used to detect thyroid problems

  -patient is scanned to see how much iodine is taken up by thyroid



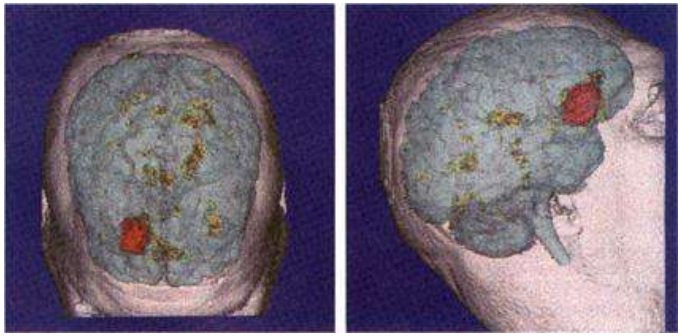



Gamma probe measuring thyroid gland radioactivity
Radioactive iodine is ingested
A.D.A.M.

Using Radiation – MEDICINE:

- **EXAMPLES**:

  -technetium-99 is used to detect brain tumors and liver disorders



  -phosphorus-32 is used to detect skin cancer

Using Radiation – CANCER TREATMENT:

- cancer cells are more susceptible to damage by gamma rays than healthy cells;
- cancerous tumors can be treated with radiation to kill cancer cells
- **RISK**: healthy cells are also damaged!