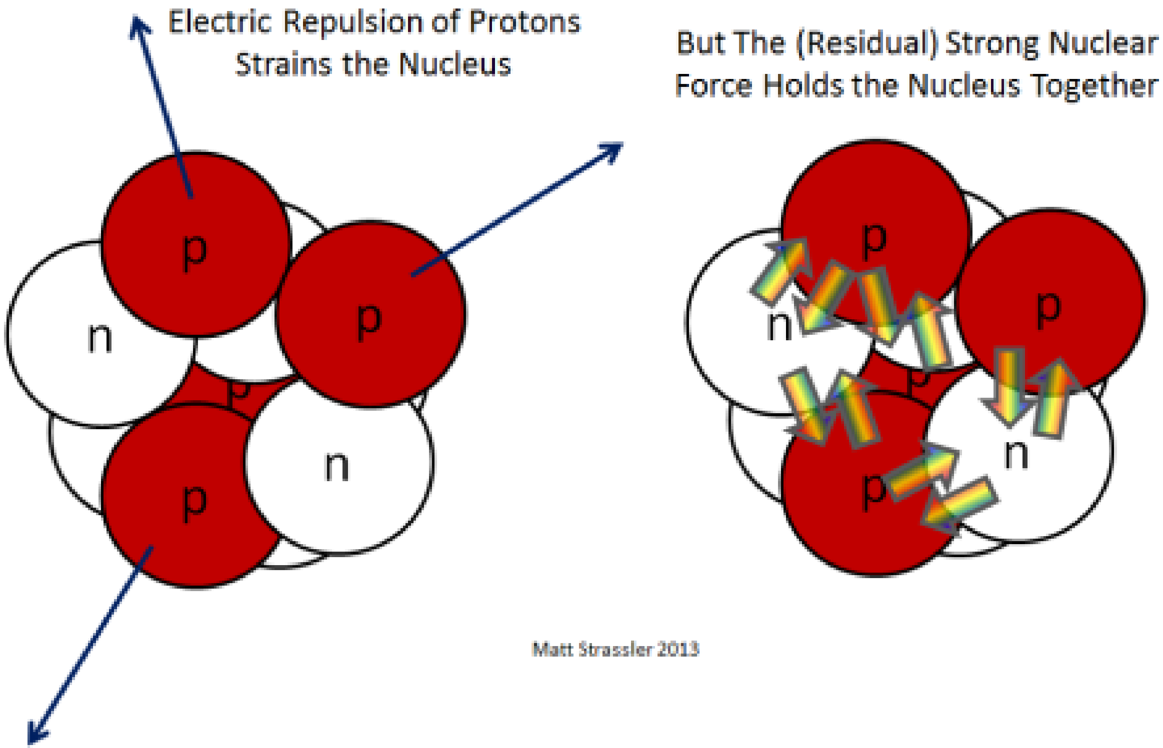
NUCLEAR ENERGY!

DAY 1: (RADIATION, FISSION, FUSION)

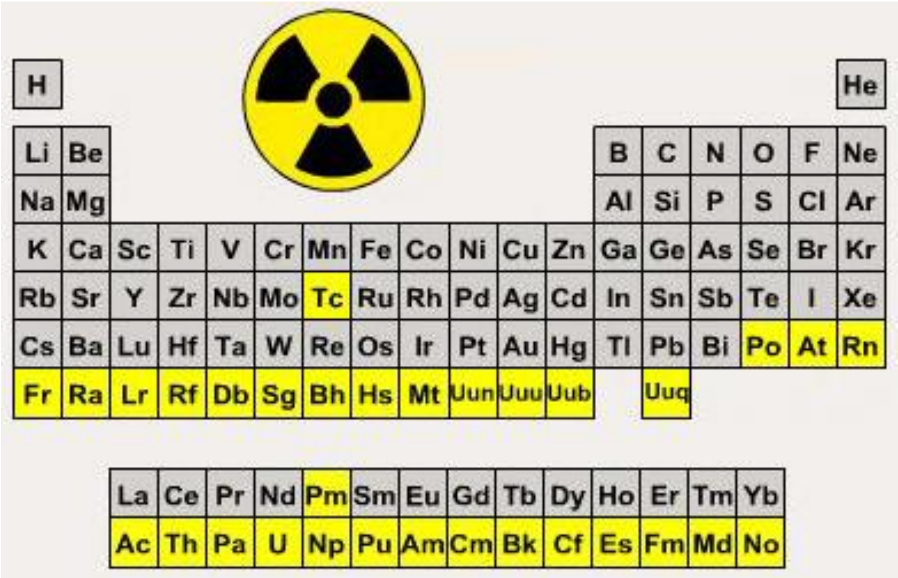
Nucleus Stability

- Stability of the nucleus depends on the nuclear forces that act between protons and neutrons
  - Protons repel each other
  - Protons attract neutrons because of the strong nuclear force



Nucleus Stability

- Nuclei with too many protons or neutrons are unstable.
  - *If an atom is unstable, it will try to become stable by splitting into two smaller atoms.*
  - *Nuclei with more than 83 protons are ALWAYS unstable*

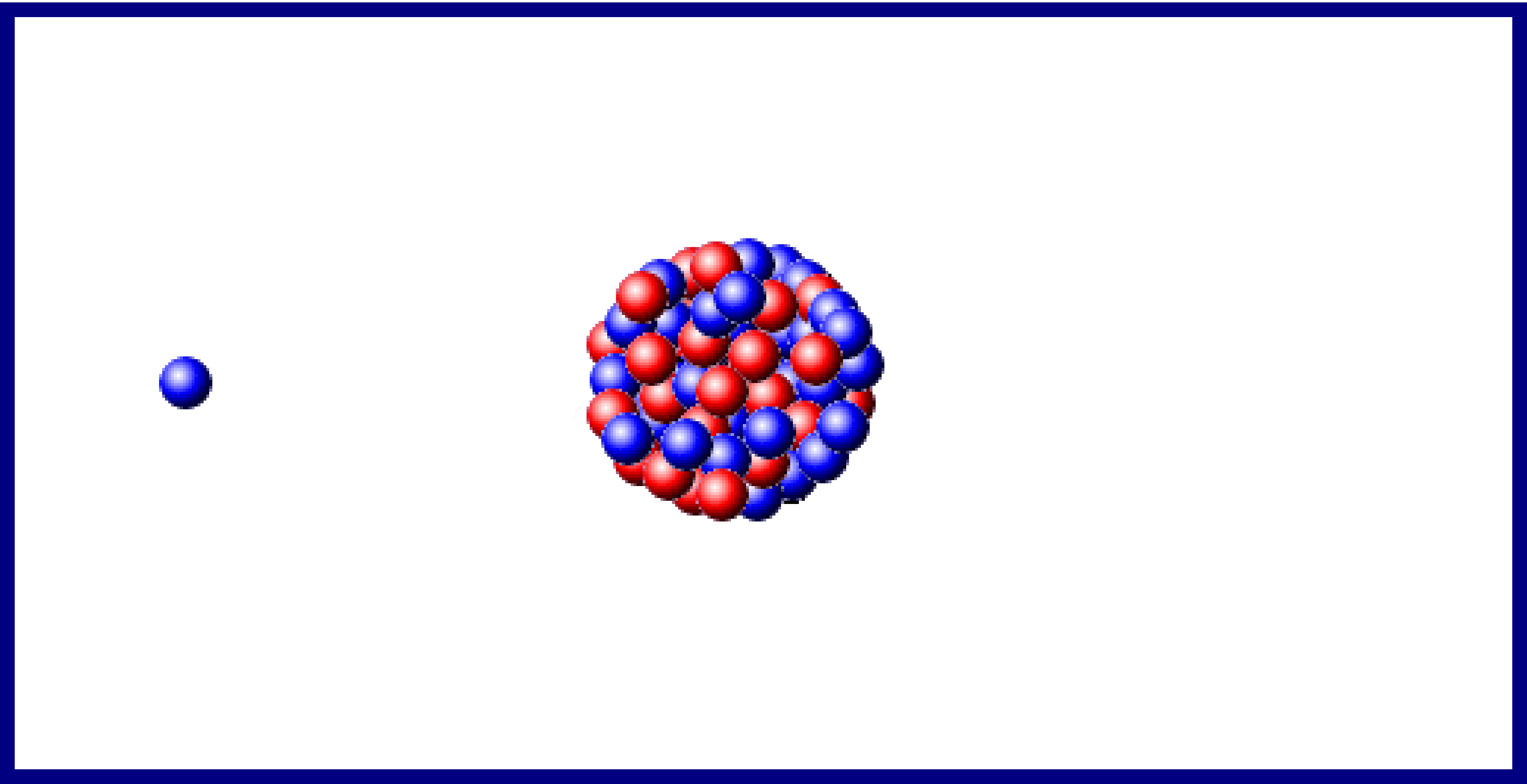


Nucleus Stability

- Essentially, nuclear stability is based on the arrangement of the protons and neutrons in the nucleus
  - *The more efficient and tightly packed the nucleus orientation is, the more stable the nucleus is*

Fission

So based on this, what is fission?



FISSION

- **Fission** is the process where a nucleus splits into two or more smaller fragments, releasing neutrons, and ***energy***
  - Nucleus must be large for this to happen

    Ex: Uranium-235

$$^{235}_{92}\mathrm{U} + ^{1}_{0}n \rightarrow ^{140}_{56}\mathrm{Ba} + ^{93}_{36}\mathrm{Kr} + 3^{1}_{0}n$$

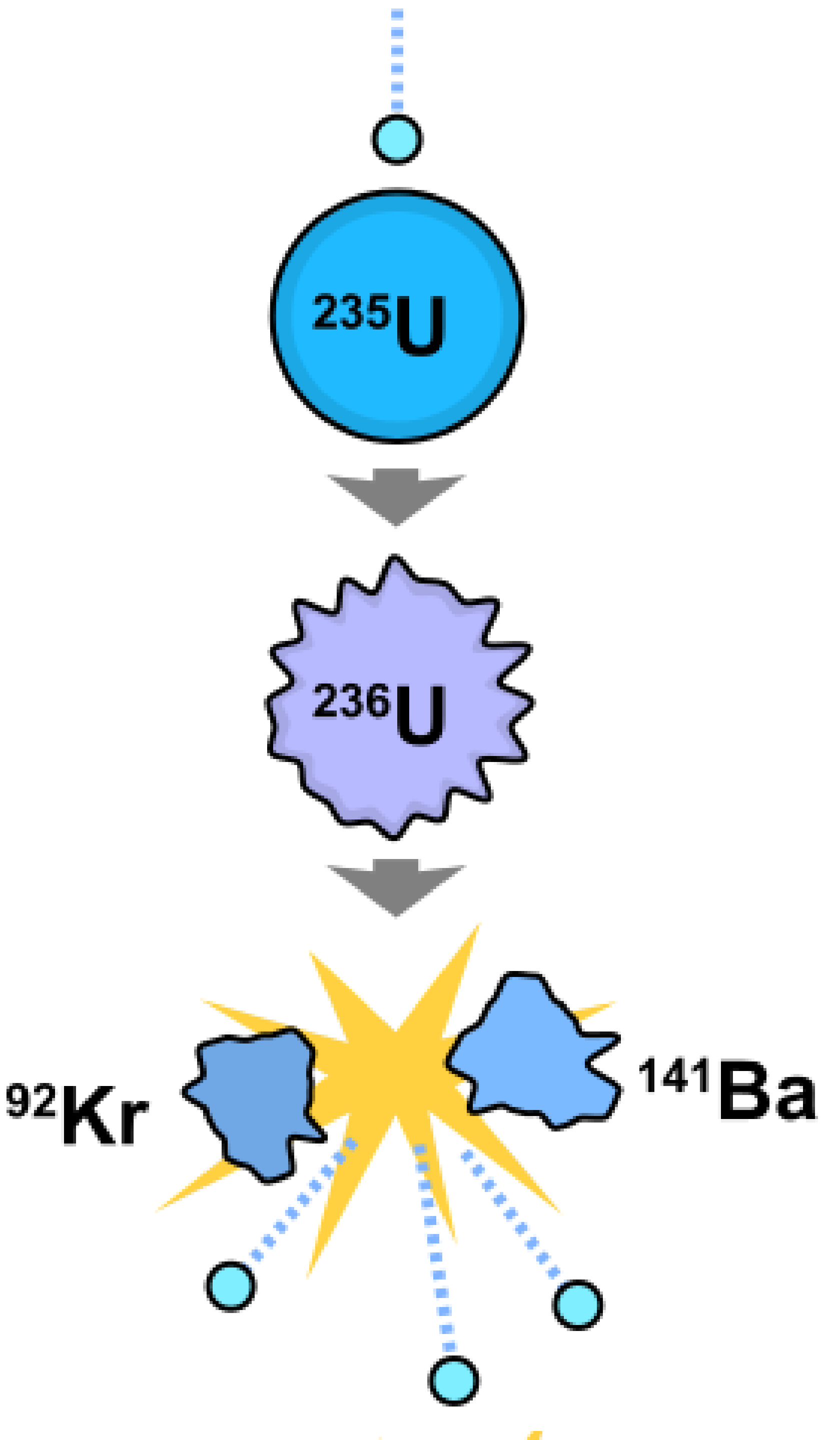
Uranium-235 only makes up 0.7% of the Uranium in the world

The rest is stable Uranium-238 – The largest naturally occurring element

- Done in nuclear power plants and atomic bombs

FISSION

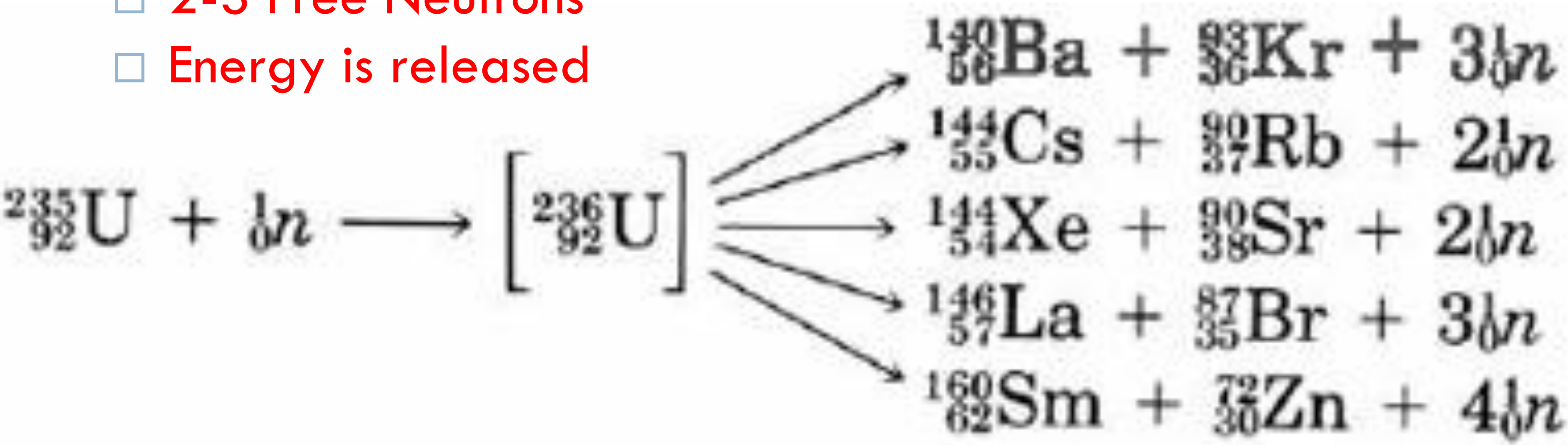
- Neutrons are used as bullets to break apart the uranium-235 nucleus.
- 3 Products form
  - Fission Products: Barium and Krypton
  - 3 Free Neutrons
  - Energy is released



FISSION: Multiple Pathways

- There are a multiple pathways for Uranium to decay
  - The pathway we concentrate on involves Ba and Kr products

- In any case, there will always be 3 products, regardless of pathway.
  - Fission Products
  - 2-3 Free Neutrons
  - Energy is released

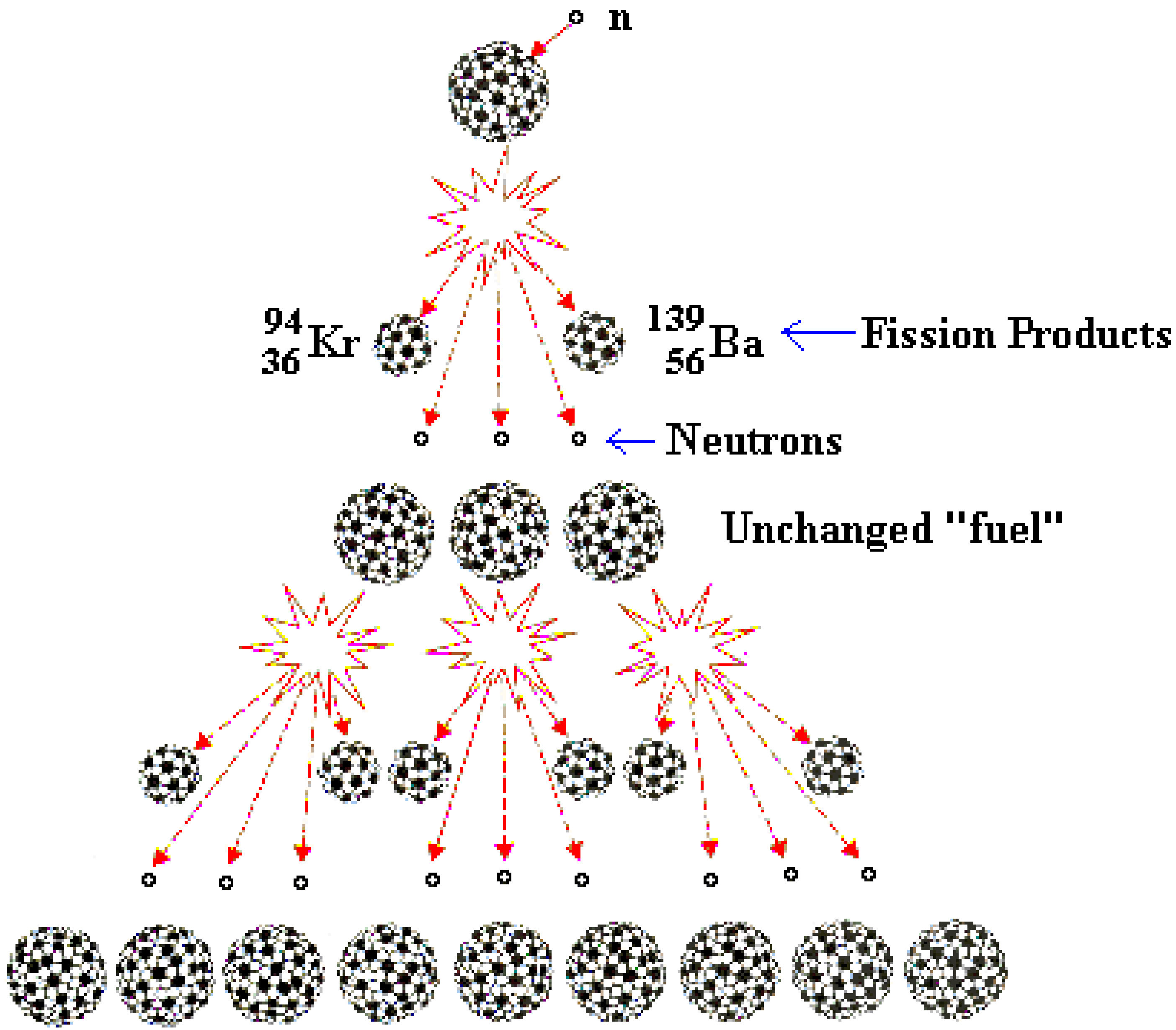


Chain Reactions

- **Chain Reaction:** The 3 neutrons that are released from fission start an additional fission reaction in a different U-235 nucleus
  - This produces more neutrons and repeats.
  - The process may be
    - controlled (nuclear power plants/submarines)
    - uncontrolled (nuclear weapons).

- Video – Chain Reaction with M Traps (3 min)

Chain Reactions



FISSION ENERGY

- Hahn and Strassman found that the overall **mass decreases** after the reaction happens.
- The missing mass changed into energy
  - $E = mc^2$
  - Energy = mass * speed of light^2
    - Speed of light = 300,000,000 m/s
- Sooo…
  - $E = mc^2$
  - $E = (1kg) * (300{,}000{,}000 m/s)^2$
  - E = 90,000,000,000,000,000 Joules
  - $E = 9x10^{16}$ joules

FISSION ENERGY

- Converting 1 kg of Uranium-235 into energy.
  - $E = mc^2$
  - $E = (1kg) * (300{,}000{,}000 m/s)^2$
  - E = 90,000,000,000,000,000 Joules
  - $E = 9 \times 10^{16}$ joules

  - Energy produced burning 1 kg of coal (not using $E = mc^2$)
  - E = 31,000,000 joules
  - $E = 3.1 \times 10^7$ joule

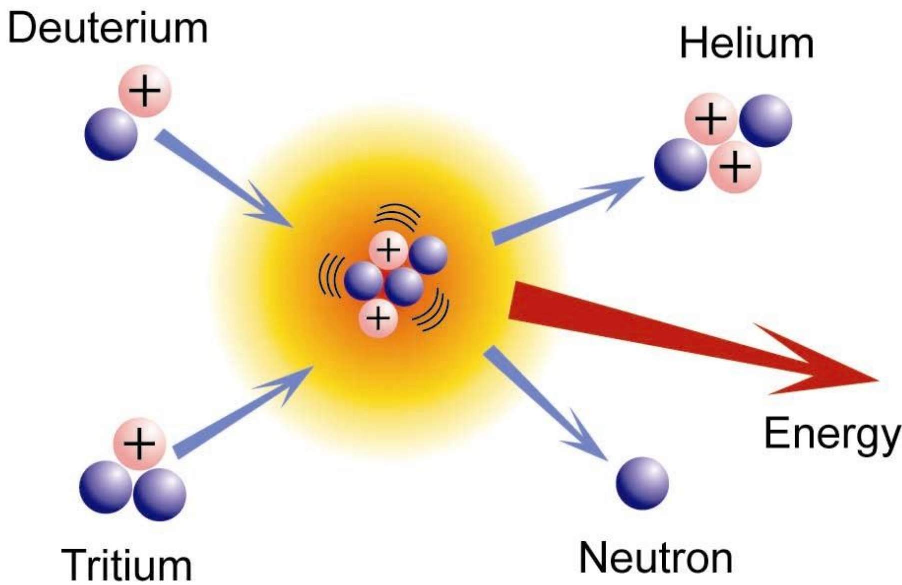
- So: 1kg of Uranium 235, undergoing fission, will produce over *1 trillion* times the energy of 1kg of coal being burned
- Video: Fission Reactions (2 min)

FUSION

- So based on this, what is fusion?

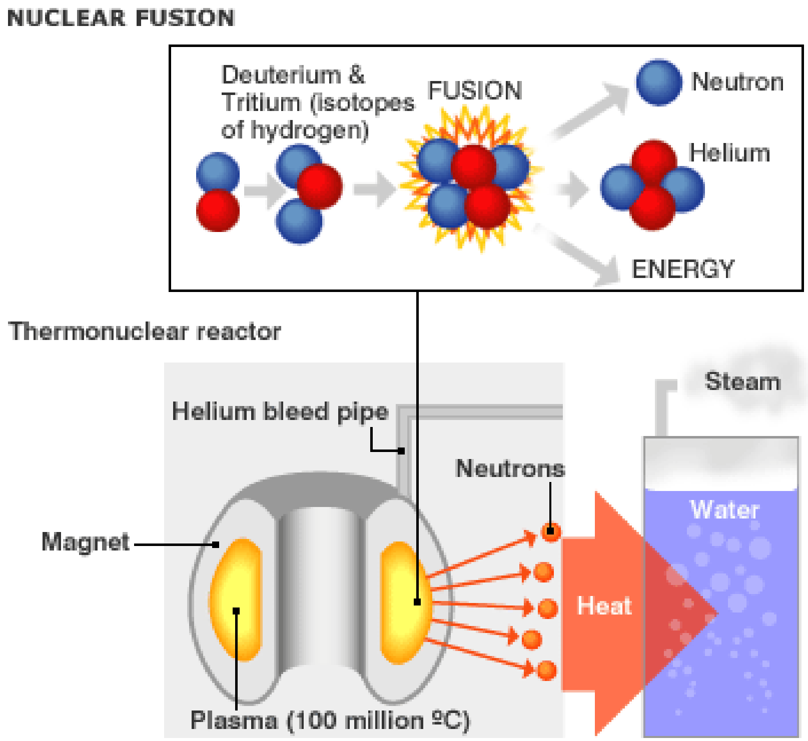
FUSION

- Two lighter nuclei combine to form a heavier nucleus
- Start with:
  - 2 Hydrogen isotopes (deuterium and tritium)
- End with with:
  - 1 Helium atom
  - 1 Neutron
  - Energy
- Occurs in stars/the sun

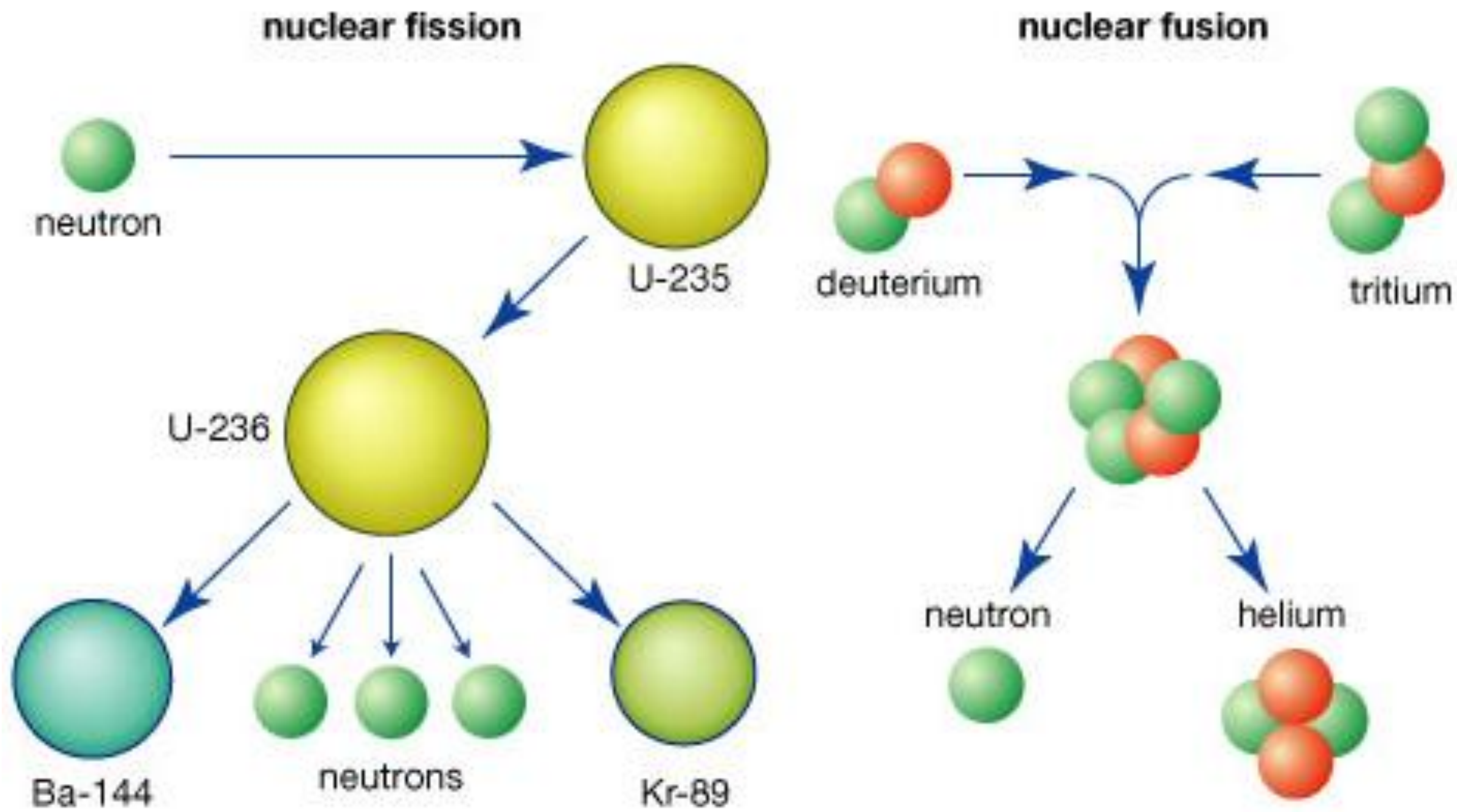


ENERGY IN FUSION

- A large amount of energy is needed to create very high temperatures so that the isotopes can be hurled at each other and overcome the tendency of positively charged nuclei (the Hydrogen isotopes) to repel each other.
- This is why FUSION occurs in Stars and our Sun
- Video – Sun's Energy (6 min)



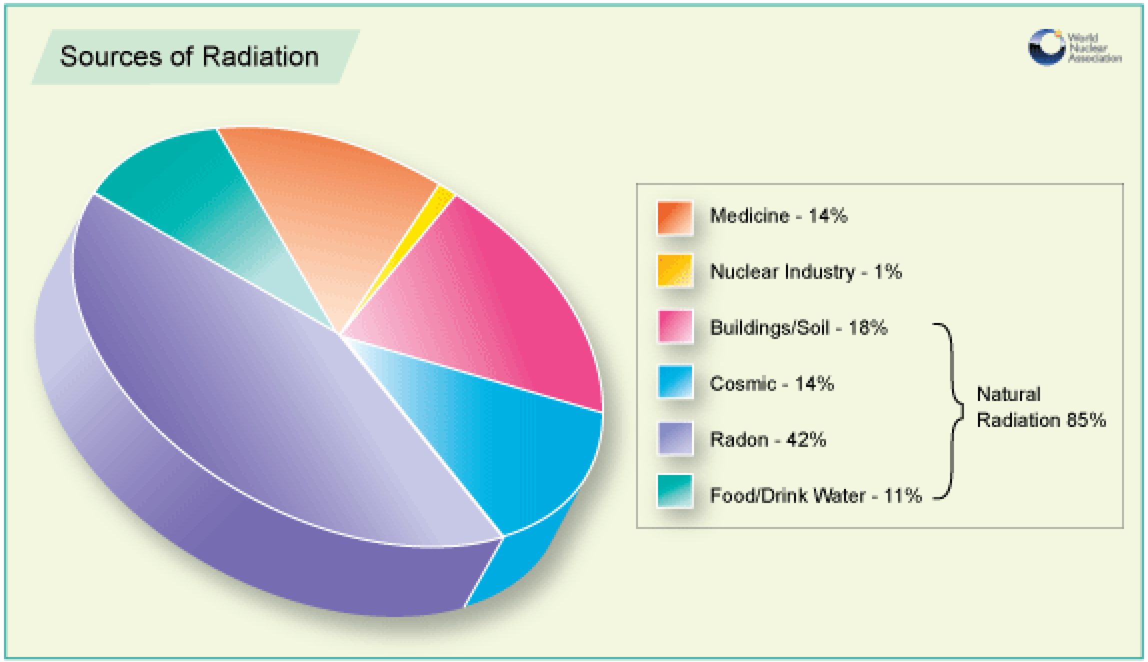
A Recap



- And don’t forget that both release energy!

Nuclear Radiation

- Radiation:
  - Emission of energy or particles from an unstable decaying atom



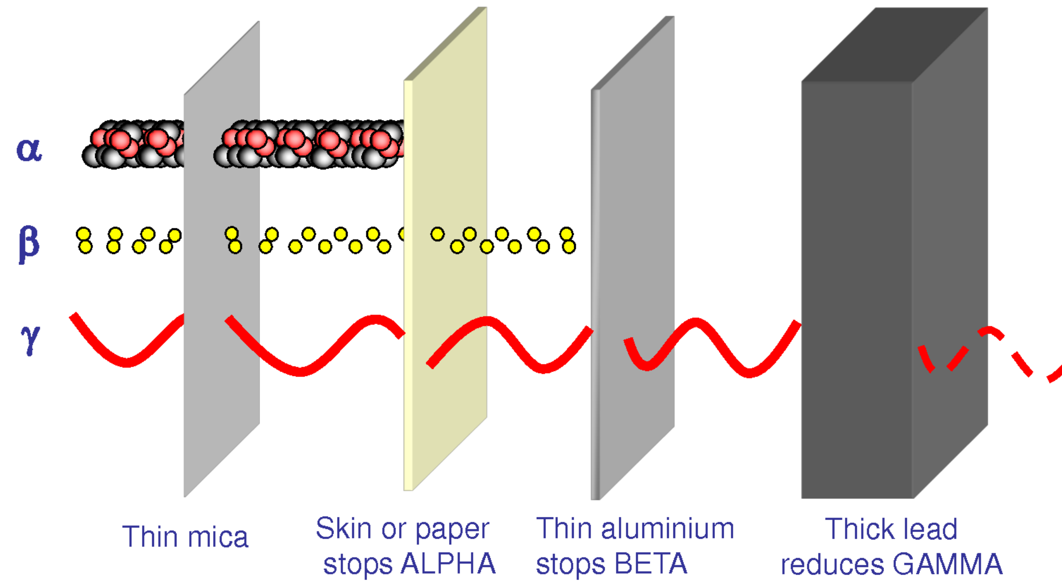
Nuclear Radiation

- Background radiation:
  - Radiation that arises naturally from cosmic rays from radioactive isotopes in the soil and air
  - Continuously exposed to radiation from natural sources:
    - sun, soil, rocks, plants
      - More than 80% of radiation exposure due to natural sources
  - You can change your exposure based on many things:
    - Air travel, where you live, smoking, x rays, job, etc…

Nuclear Radiation

- Radiation comes in 3 forms:
  - Alpha particles
  - Beta particle
  - Gamma particle

The penetration power of the three types of radiation.



NUCLEAR ENERGY!

DAY 2: (USES, PROS, CONS)

Ways We Use Nuclear Energy

- Nuclear Medicine
- Nuclear Weapons
- Nuclear Power
  - Nuclear power plants
  - Nuclear submarines

Nuclear Medicines

Nuclear Medicine: The use of radioactive substances in the diagnosis or treatment of diseases

POSITIVE:

- Check body systems to make sure working properly
  - Radiopharmaceuticals are taken orally and then a "gamma camera" captures images of emitted radiation from inside body
- Nuclear Medicine Therapy- Intravenous or oral administered drug
  - Used to treat conditions such as hyperthyroidism, thyroid cancer, and blood disorders

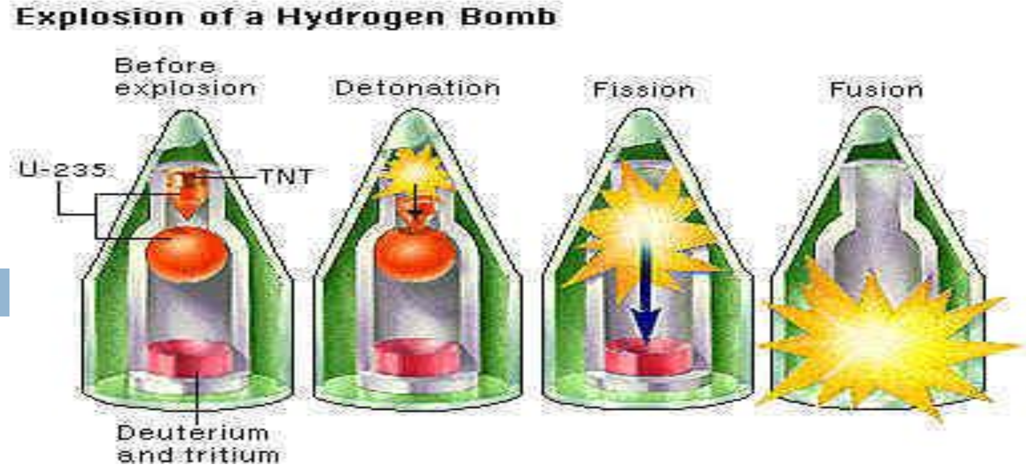
Nuclear Medicines

Nuclear Medicine: The use of radioactive substances in the diagnosis or treatment of diseases

NEGATIVE:

- Produces mild radiation, so it can damage/cause cancer in healthy cells
- Nuclear waste must be stored
- VERY expensive to set up in a facility

Nuclear Weapons



- **This is a "Uncontrolled Fission Reaction"**
- Tremendous amounts of energy available from small amounts of fuel
  - can be "smuggled easily."
- Tremendous amount of destruction
- Contamination of the environment for very long amounts of time

- Video: Top 10 explosions ever http://www.youtube.com/watch?v=yRRGaxx8Zf4 (4 min)
- Video: Effects of a nuclear bomb http://www.youtube.com/watch?v=Aza-2wopCFY (4 minutes)
- Video: Time lapse of every nuclear explosion ever http://www.youtube.com/watch?v=gJe7fY-yowk (5 min)

Nuclear Test Underground…

Tsar Bomb (biggest nuke ever…)

Tsar Bomb (biggest nuke ever…)

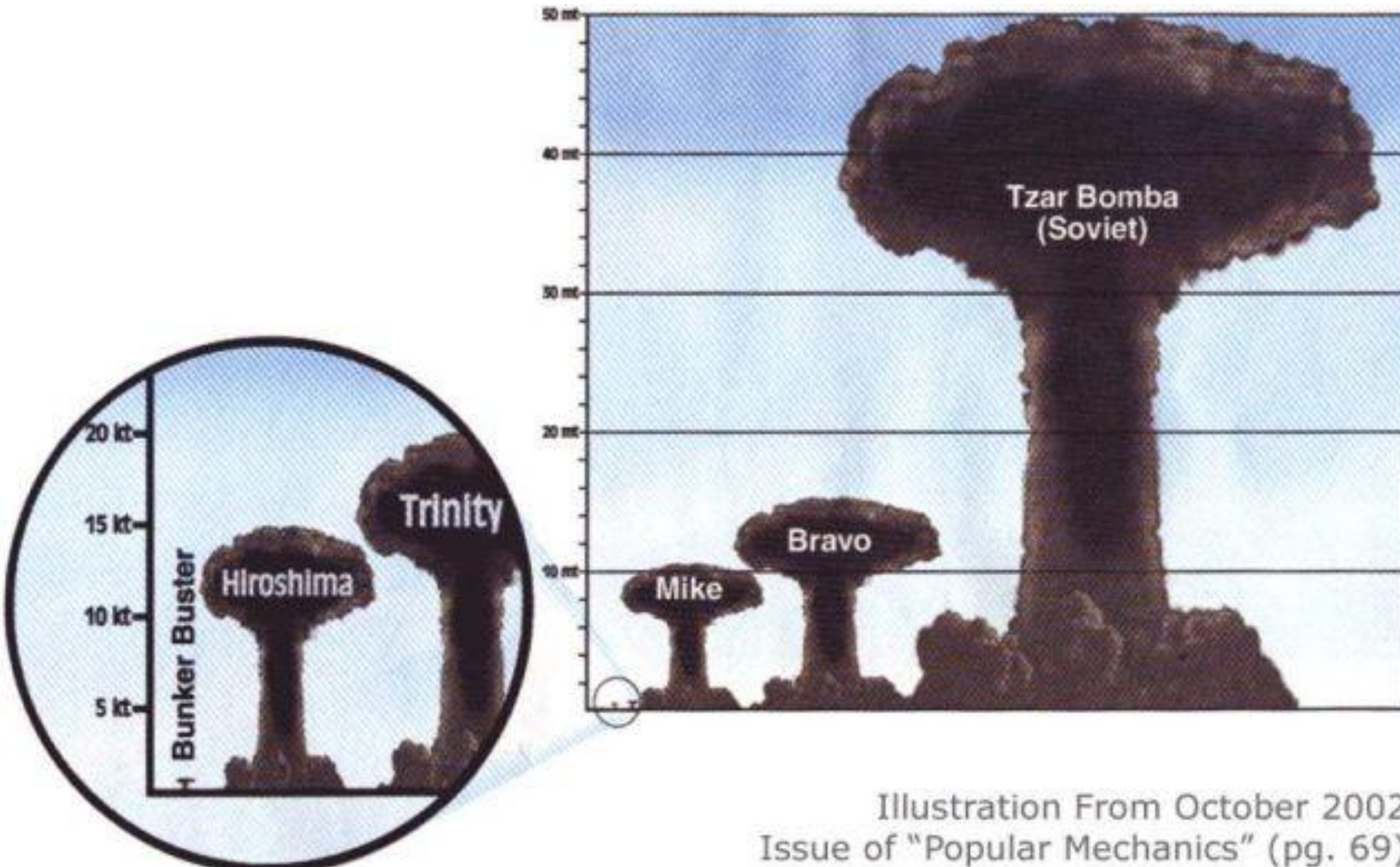
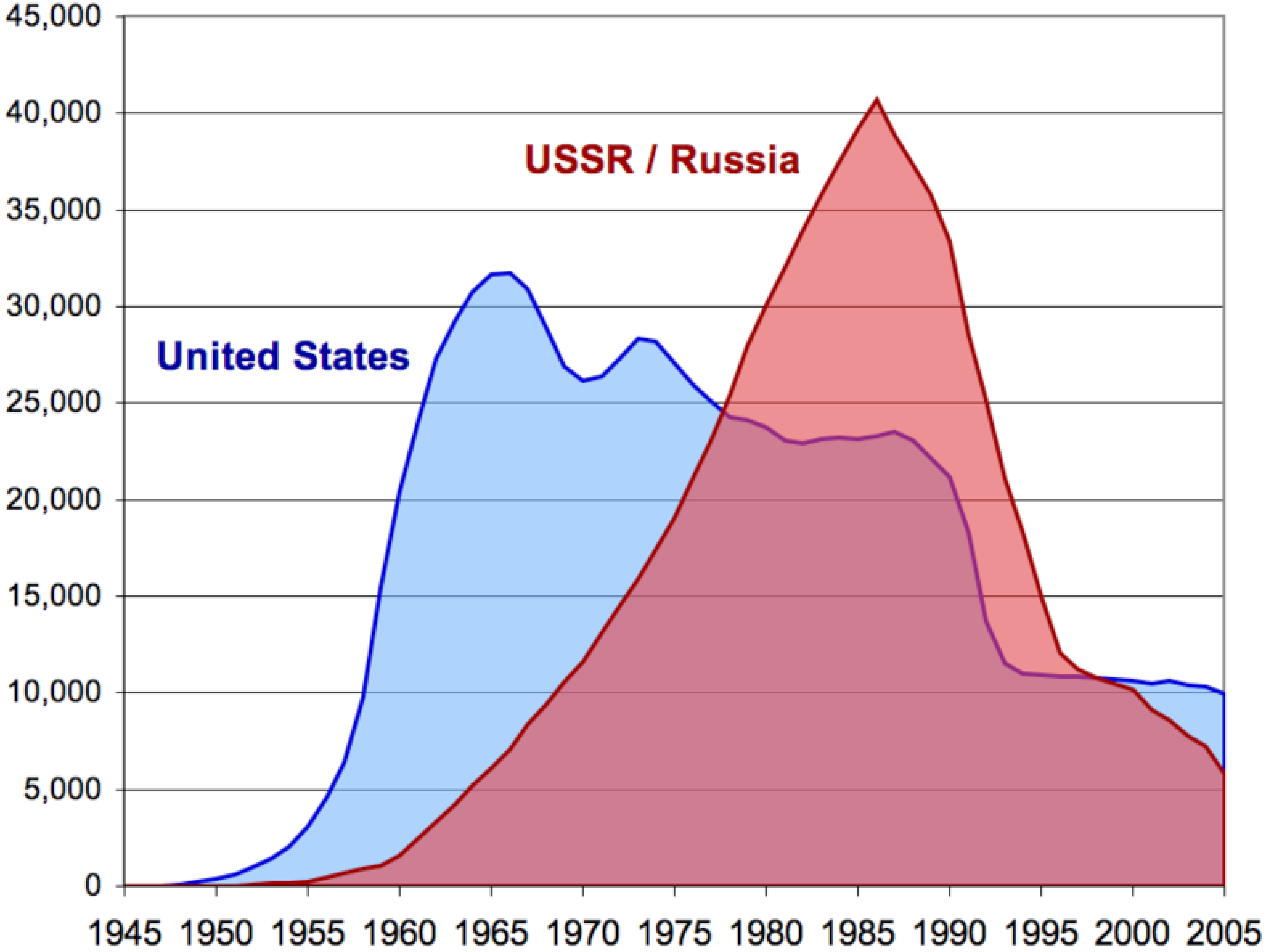
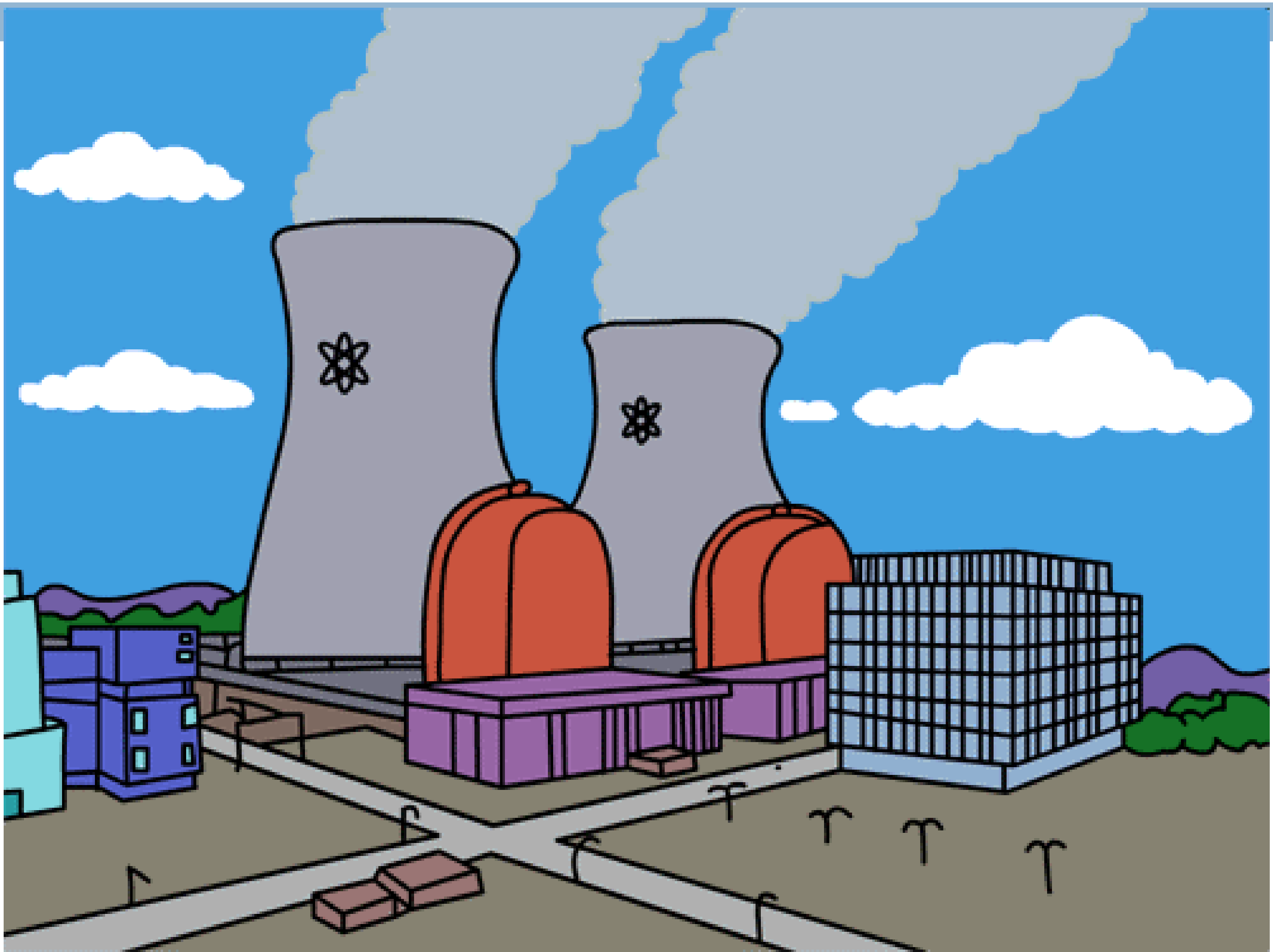


Illustration From October 2002
Issue of "Popular Mechanics" (pg. 69)

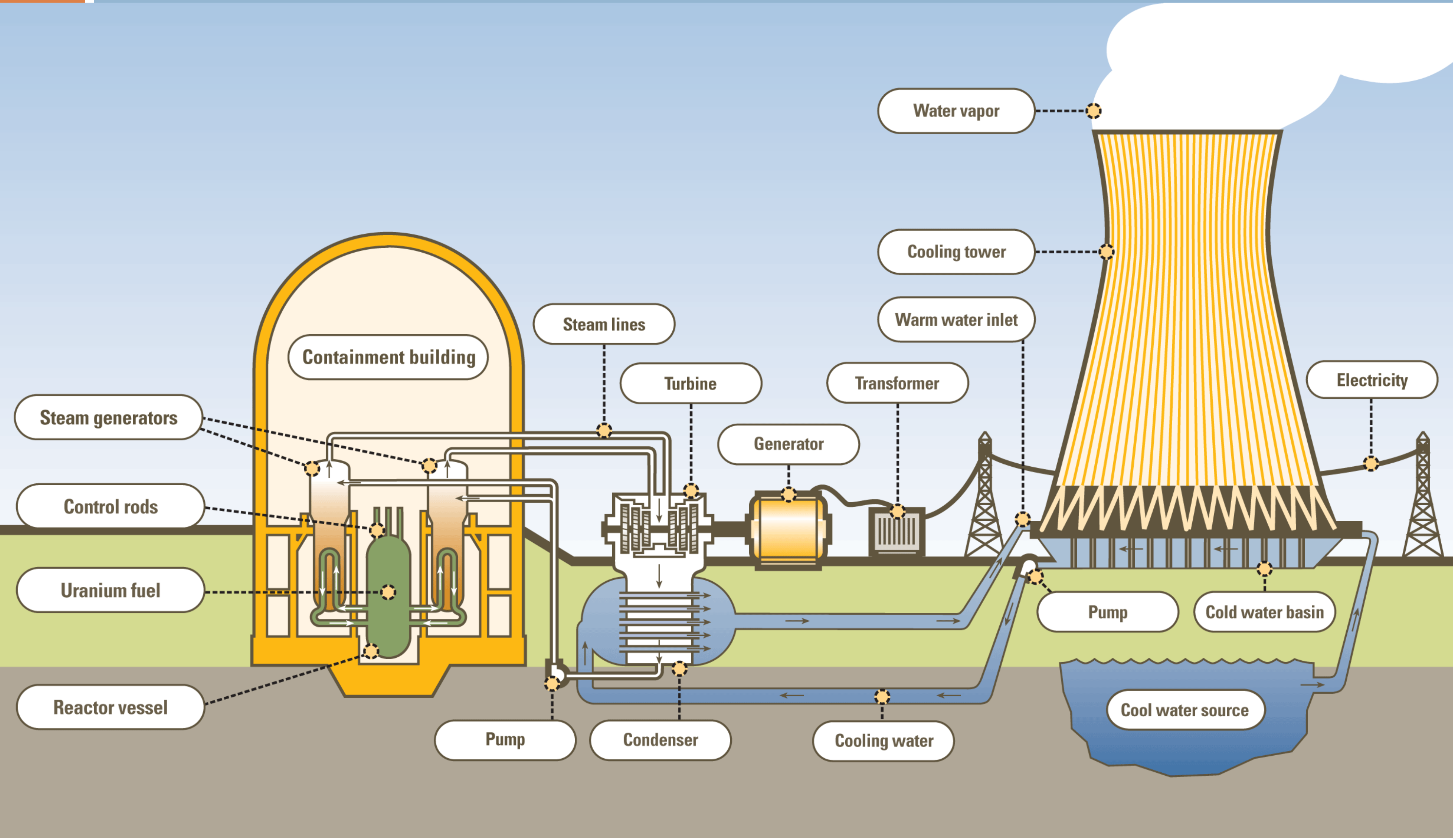
Nuclear Weapons



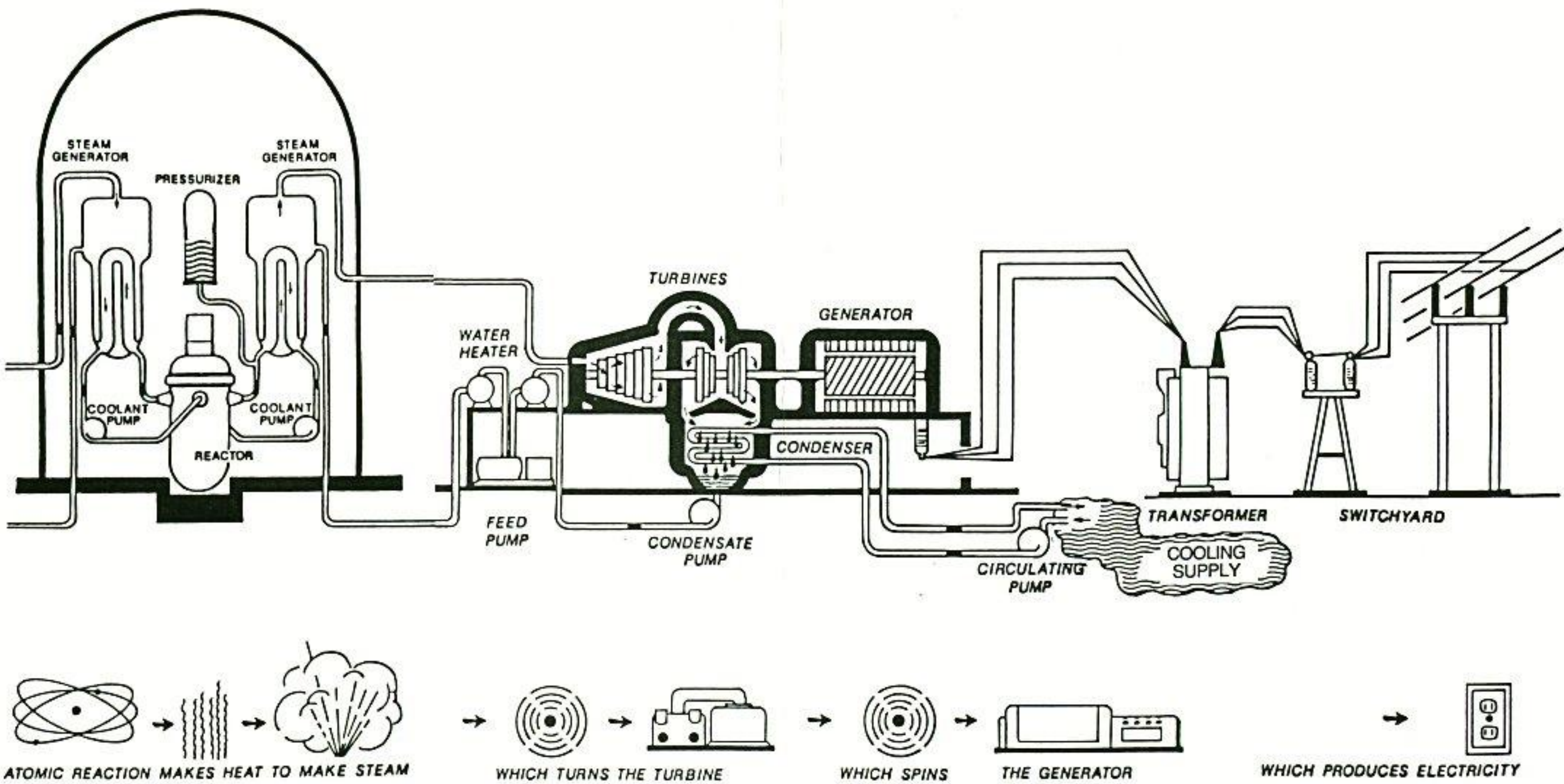
Nuclear Reactor: How It Works



Nuclear Reactor: This is a Controlled Nuclear Fission Reaction

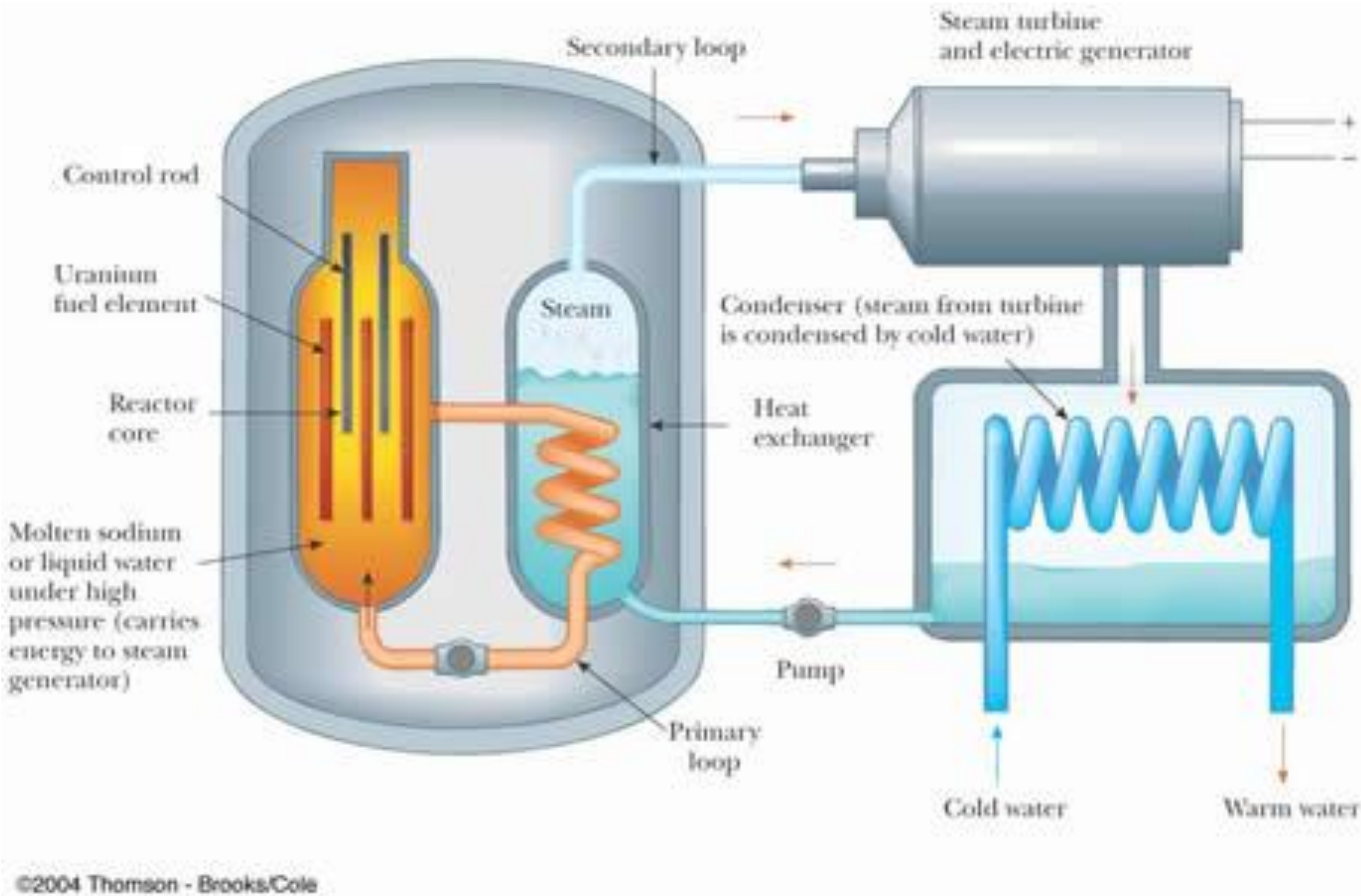


Nuclear Reactor: This is a Controlled Nuclear Fission Reaction



Nuclear Reactor: How it works

Video (5 min) http://www.youtube.com/watch?v=PKNbwclaGng

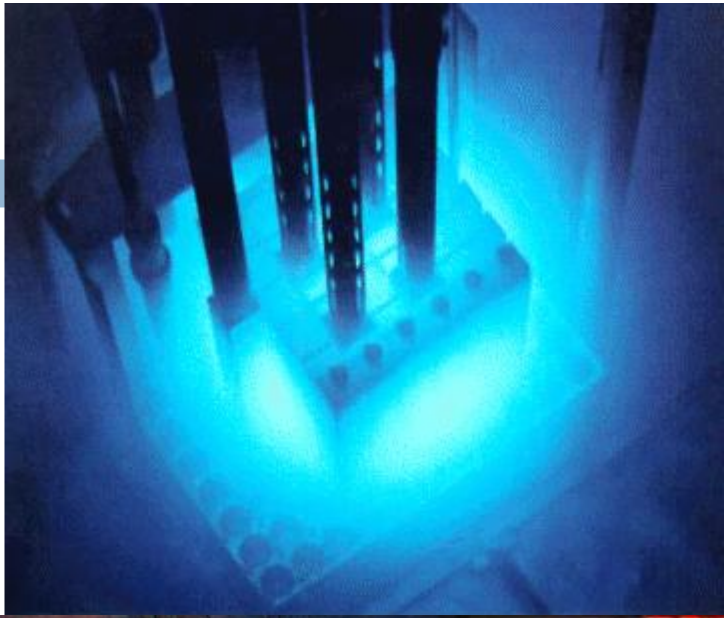


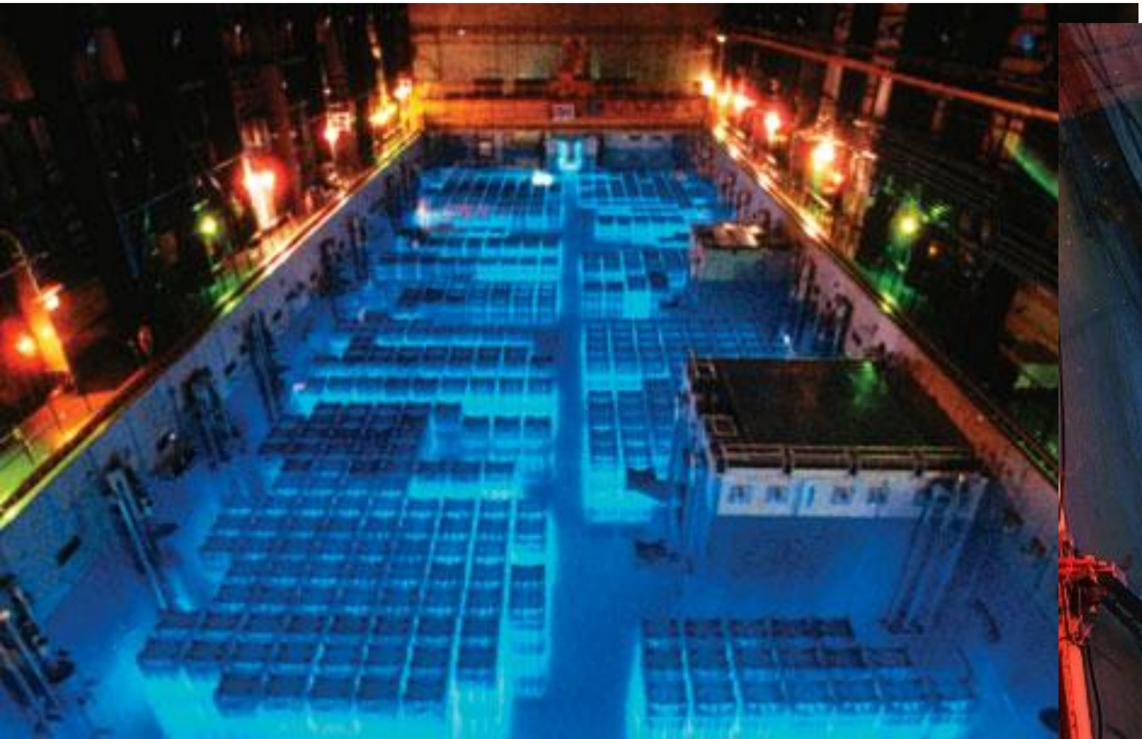
Nuclear Energy in 4 easy steps:

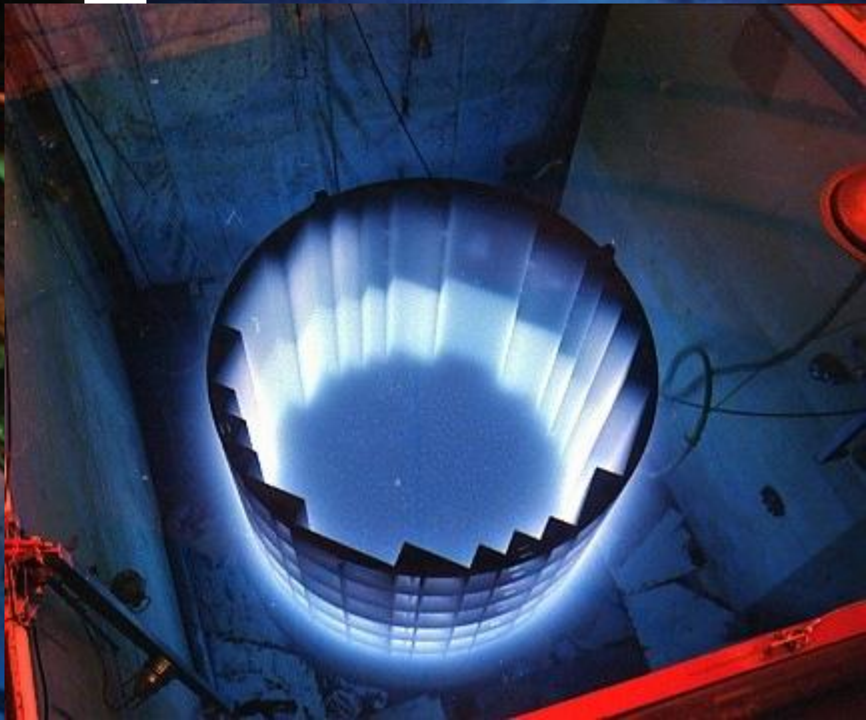
- 1) A Fission chain reaction begins while the fuel rods are in the water
  - The amount of fission is controlled by lead *Control Rods*
- 2) The water heats up and changes to steam
- 3) The steam turns a turbine
- 4) The turbine turns a generator, forming electricity
- The steam is then cooled down in a cooling tower
- The spent fuel rods need to be stored for hundreds/thousands of years

Nuclear Energy:

- Used Fuel Rods

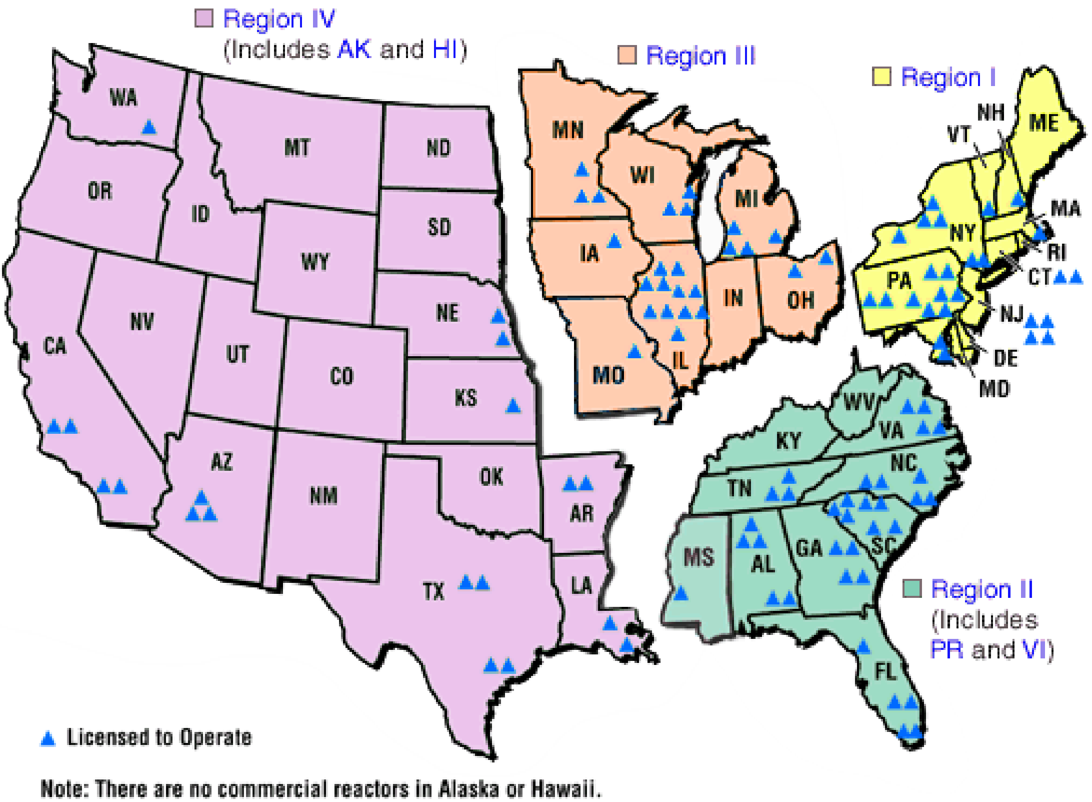






Nuclear Energy: Where Are They

- 65 Nuclear Power Plants in the United States
  - Produce 19.6% of our energy (2008)
- SC has 4 plants, producing over ½ of our energy



Nuclear Energy BENEFITS

- Tremendous amounts of energy available from small amounts of fuel
- No air pollution of greenhouse gasses from the burning of fossil fuels
- Can be used anywhere
- Abundance of fuel
- Non-reliance on fossil fuel

NUCLEAR ENERGY NEGATIVES:

- Can cause thermal pollution to water systems (if you put the hot water back into rivers)

- Waste must be stored until it is no longer radioactive – can be a very long time.
- Improper handling of nuclear materials
- Power plant failure – radioactive explosions
  - Fukushima Explained - http://www.youtube.com/watch?v=rBvUtY0PfB8 (5 min)