Sample Diploma Problem

9. The equation that can be used to determine the quantity of energy released during natural gas combustion is

A. $v = f\lambda$

B. $\Delta E = \Delta mc^2$

C. $C_iV_i = C_fV_f$

D. $\Delta_r H = \sum n\Delta_f H°$ products $- \sum n\Delta_f H°$ reactants

Sample Diploma Problem

Use the following information to answer questions 10 and 11.

Methane gas is collected from the decaying biological material in a sludge tank and is burned to produce heat and electricity for a waste-water treatment plant. The combustion of the collected methane gas is represented by the equation below.

$$CH_4(g) + 2\,O_2(g) \rightarrow CO_2(g) + 2\,H_2O(g)$$

11. The energy released from the combustion of one mole of methane gas is

A. 74.6 kJ

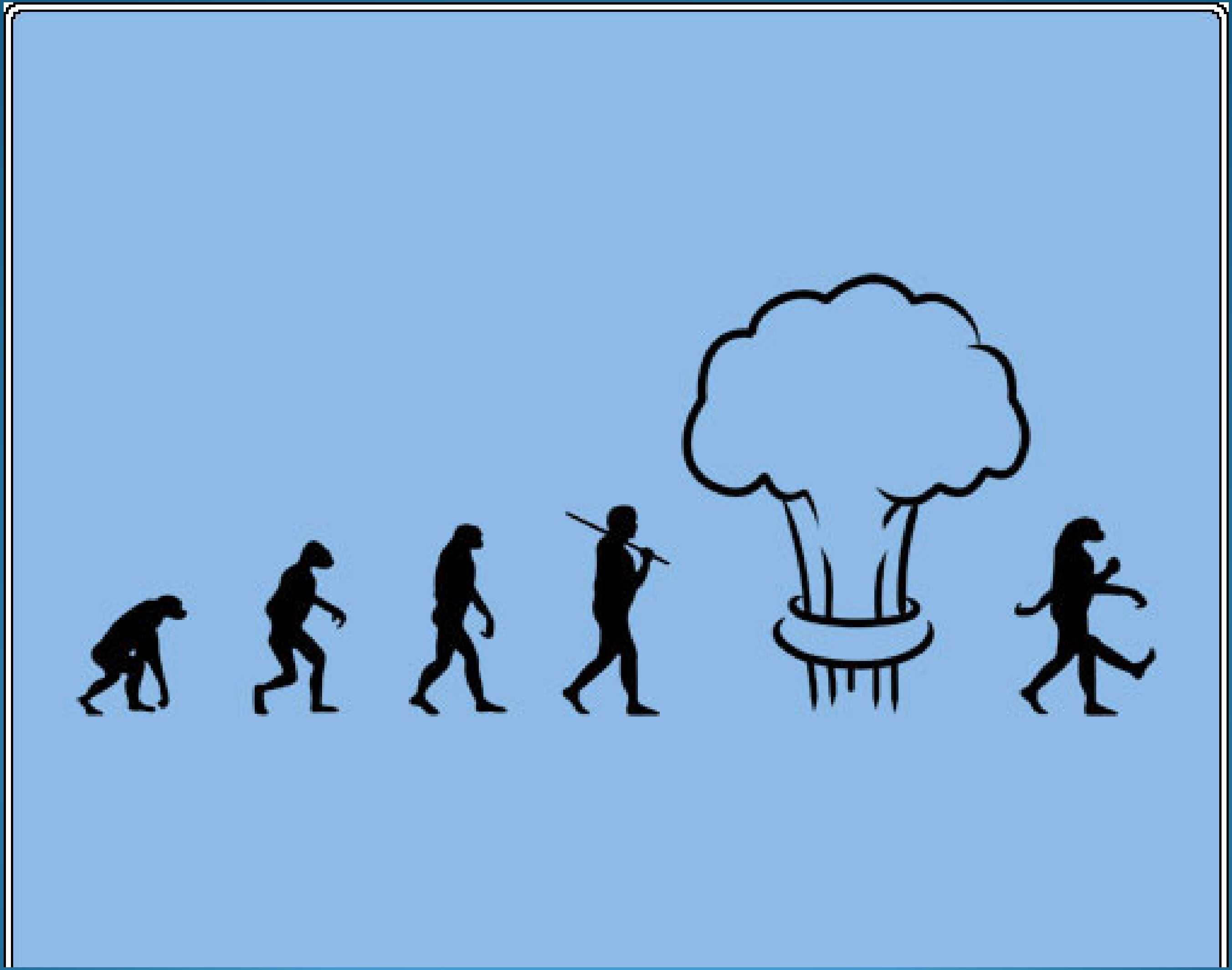
B. 560.7 kJ

C. 802.5 kJ

D. 951.7 kJ

{(-393.50) + (2*-241.8)] – [-74.6 + 0] = -802.5

Nuclear Energy



Curriculum

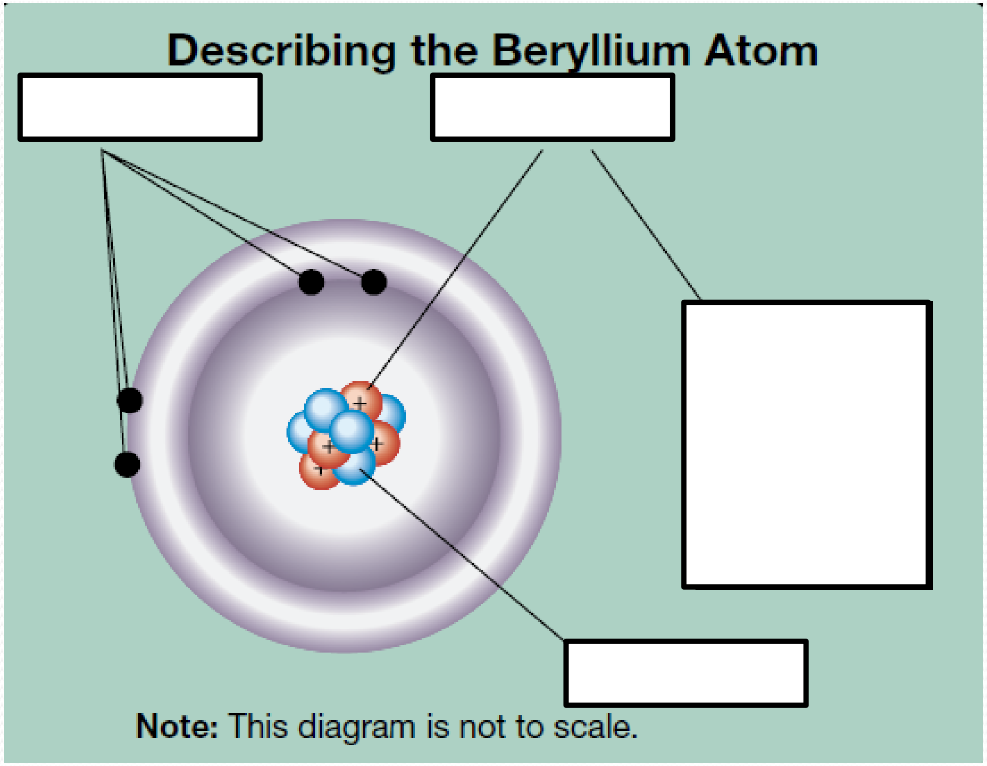
- explain the difference between fission and fusion and balance simple nuclear reaction equations to show the conservation of nucleons
- describe the main types and sources of radioactive decay and resulting ionizing radiation; i.e., alpha (α), beta (β) and gamma (γ) decay
- describe mass-energy changes in fission and fusion reactions, as represented by the formula $E = mc^2$
- describe, in general terms, the operation of a fission reactor (*e.g., the Canadian Deuterium Uranium [CANDU] Reactor*) and the current state of fusion research

Curriculum

- compare and contrast conventional coal, oil-fired or hydroelectric power stations with nuclear power stations, in terms of purpose, process of energy conversions, design and function
- contrast, quantitatively, the orders of magnitude of energy produced by nuclear, chemical and phase changes
- calculate mass-energy changes in fission and fusion reactions, using the equation $E = mc^2$

The Nucleus

- What is inside of the nucleus of the atom?



Isotopes

- Isotopes are the same elements but different masses
- What makes up the mass of an element?
- What happens if I change the number of protons?
- What happens if I change the number of neutrons?
- An isotope is the same element but with different number of nucleons

Nuclear Notation

- The chemical symbol for any given isotope is designated by stating the **atomic number (Z)** as a subscript, and the **mass number (A)** as a superscript to the left of the element's symbol
- In general, for any given **element X**:

$$^{A}_{Z}X$$

Example

Chemical Notation	Element	Atomic Number (Z)	Mass Number (A)	Number of Protons	Number of Neutrons	Number of electrons
	potassium				**21**	

Board Question

Chemical Notation	Element	Atomic Number (Z)	Mass Number (A)	Number of Protons	Number of Neutrons	Number of electrons
${}^{11}_{5}B$						

Strong Nuclear Force

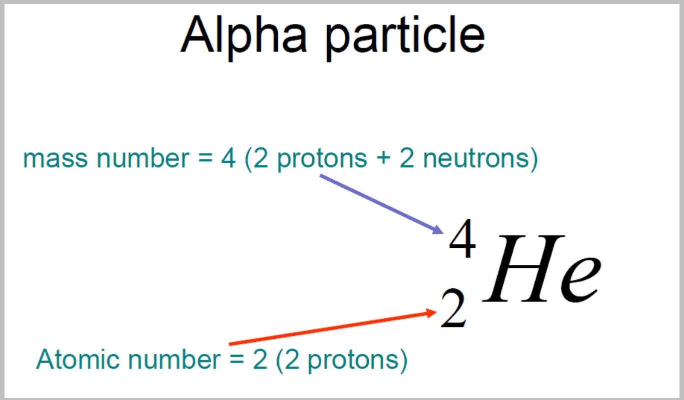
- The **strong nuclear force** is what holds the nucleus together
- The strong nuclear force is stronger than gravity and electric and magnetic forces
- When a nucleus is too unstable, it will break apart in a process called **radioactive decay**
- After a radioactive decay the nucleus will be more stable

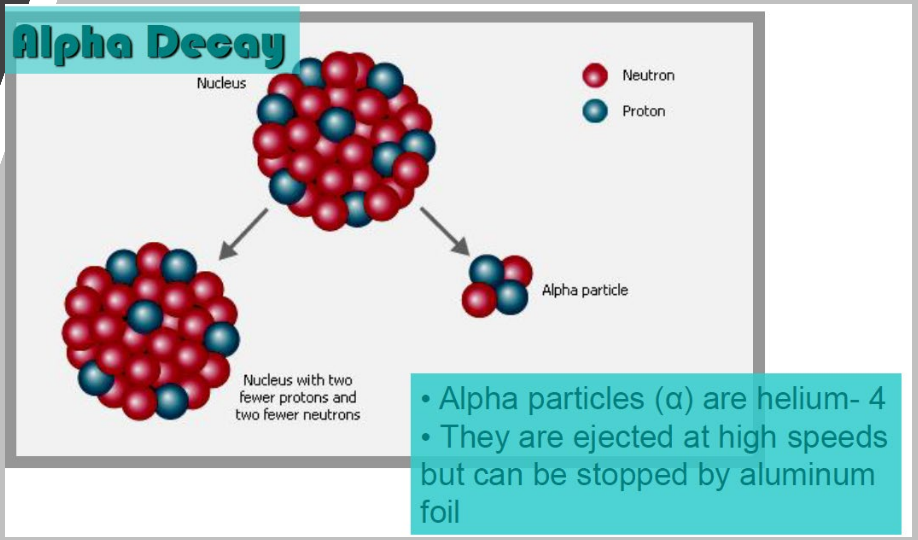
Alpha Radiation

- An **alpha particle** *is two neutrons and two protons stuck together*
- It is the same as a helium nucleus without electrons
- It can be represented in two ways:

He -4

α

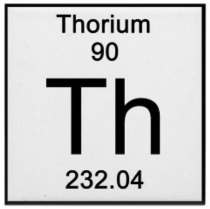




Example

- Many smoke detectors contain the ***<u>isotope americium-241</u>***. Alpha particles emitted during the decay of americium-241 ionize molecules in the air, allowing an electric current to flow between two plates in the smoke detector. During a fire, smoke particles that come between these two plates interfere with the current, setting off the detector's alarm.
- Write the alpha decay equation for this
  - Reactant (Americium 241) → alpha + unknown

Board Question

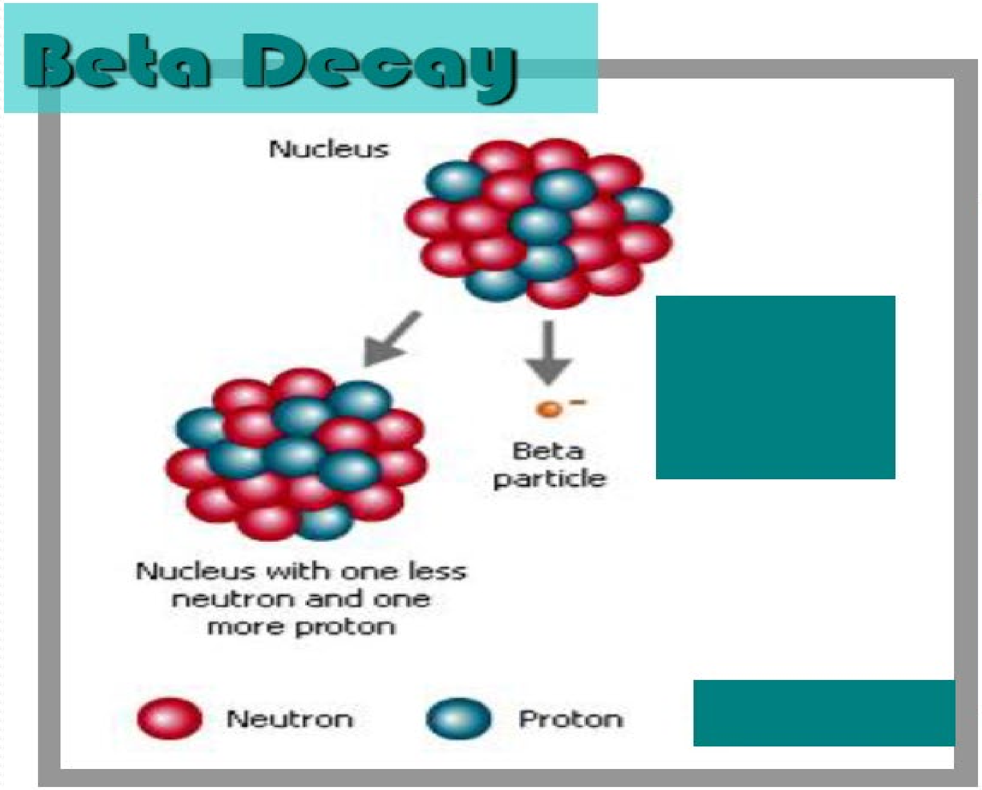


- Write the nuclear equation for the alpha decay of thorium-230.

$$^{230}_{90}Th \rightarrow\ ^{226}_{88}Ra + ^{4}_{2}He$$

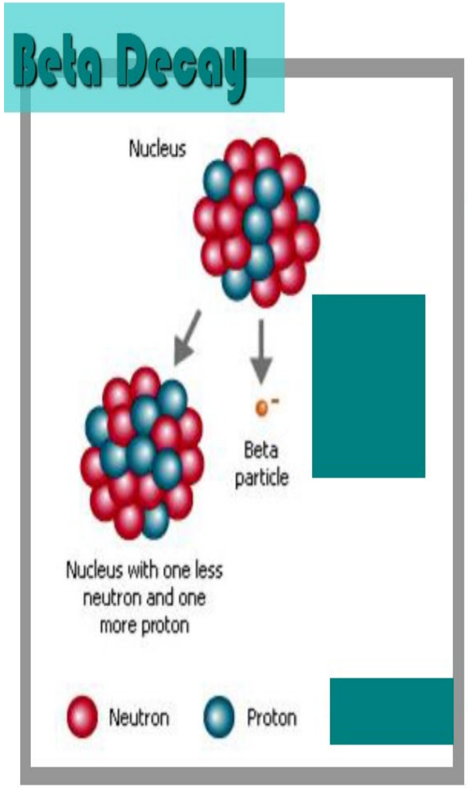
Beta Radiation

- Another way for nucleus to become more stable is to shoot off an electron, which is called **beta radiation**
- A beta particle can be expressed two ways:



- A neutron decays into a proton and an electron.
- The electron is ejected from the nucleus at a high speed – called a beta particle (β).
- β particles can penetrate several mm of lead.

Beta particle



- A neutron decays into a proton and an electron.
- The electron is ejected from the nucleus at a high speed – called a beta particle (β).
- β particles can penetrate several mm of lead.

Beta particle is an electron formed when a neutron changes into a proton

Mass number = 0 because the mass is so small, it can be ignored

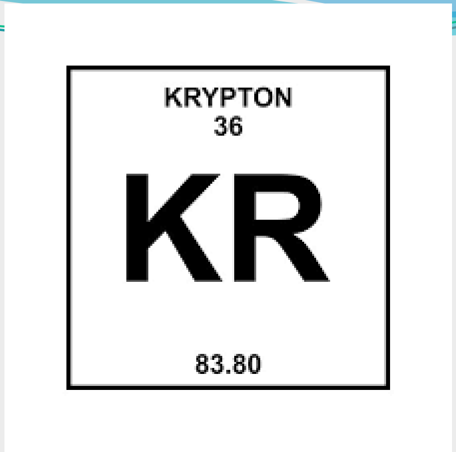
$$^{0}_{-1}e$$

Charge

Example

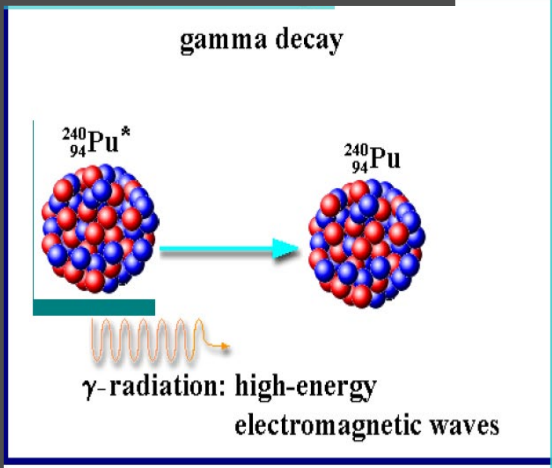
- Carbon 14 undergoes beta decay. Write out the reaction

Board Question



- Show a beta decay of krypton-87

Gamma Radiation



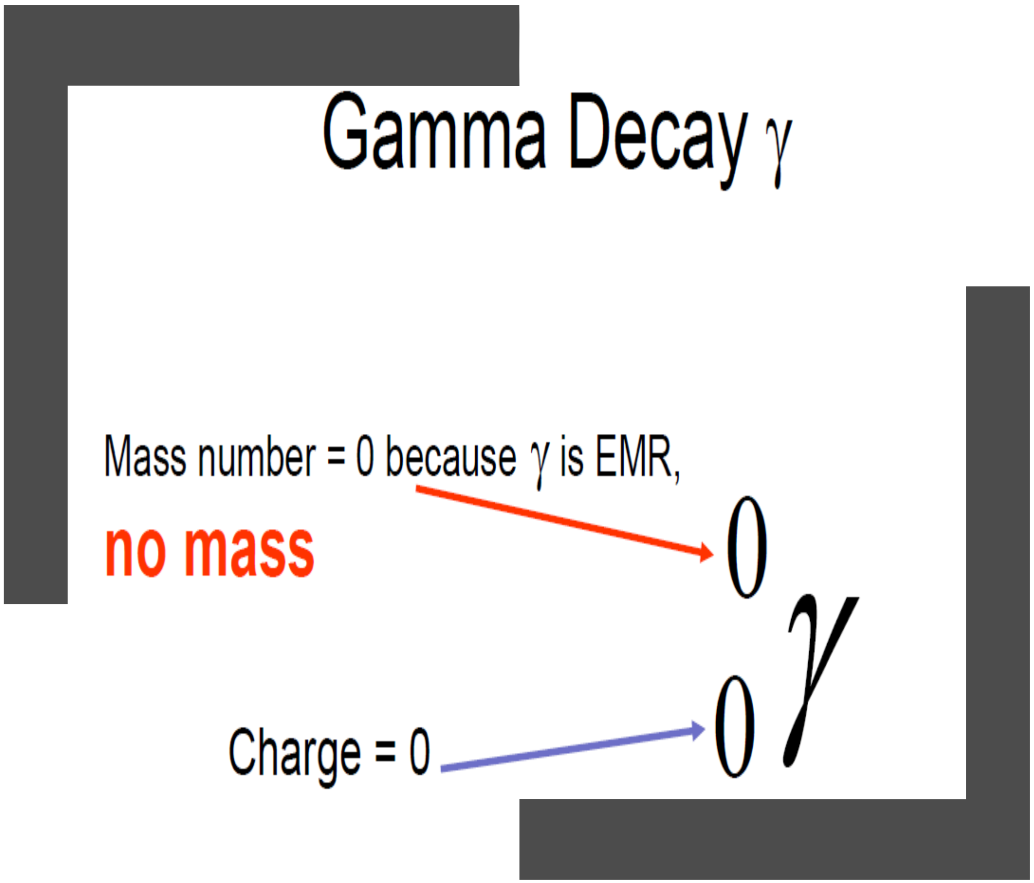
- Gamma rays can be emitted along with an alpha or beta particle.
- When a nucleus emits only a gamma (*γ*) ray, the energy of the nucleus is reduced but the mass number and the atomic numbers stay the same.
- *γ rays can penetrate many cm of lead.*

$$^{60}_{27}Co^* \rightarrow {}^{60}_{27}Co + \gamma$$

exited *unexcited*

- Alpha and beta radiation emits a stream of particles
- **Gamma radiation** is an electromagnetic wave

Gamma radiation



- Because it has no mass and no charge and can be expressed like this:
- When a nucleus undergoes decay it can get excited and to deexcite it gives off a gamma ray

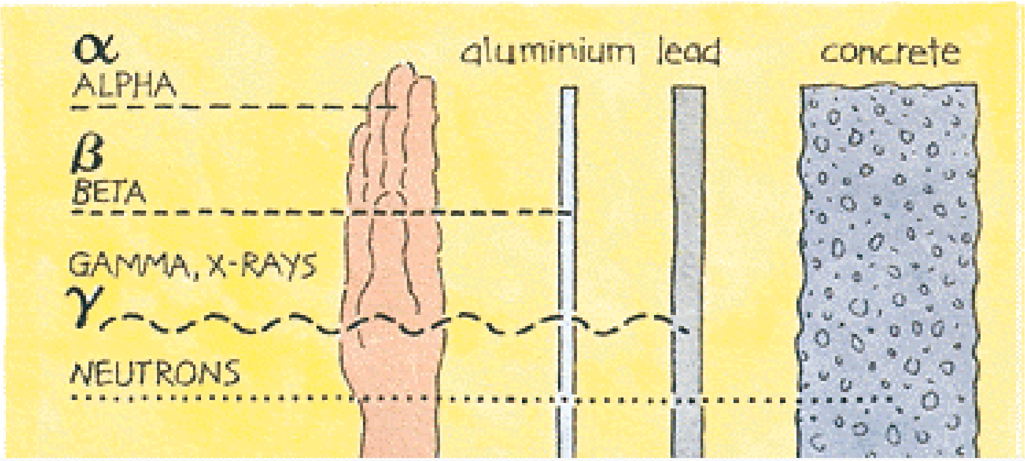
Gamma decay

$$^{227}_{90}\mathrm{Th} \longrightarrow \underset{\text{excited}}{^{223}_{88}\mathrm{Ra}} + {}^{4}_{2}\mathrm{He}$$

$$\underset{\text{excited}}{^{223}_{88}\mathrm{Ra}} \longrightarrow \underset{\text{unexcited}}{^{223}_{88}\mathrm{Ra}} + \gamma$$

Dangers of Radiation

- Gamma radiation has very high energy and radiation that is ionizing can damage DNA
- To detect radiation a device called a **Geiger counter** is used
- Because each type of radiation is different, they all have different penetrating abilities

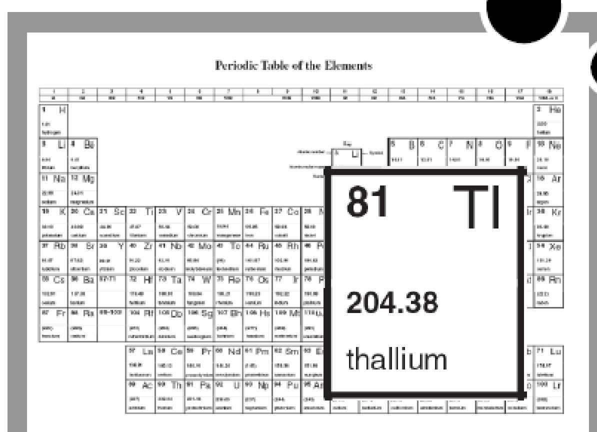


Example 1: Complete the equation:

$$^{210}_{83}Bi \rightarrow ^{4}_{2}He + \_\_\_\_\_$$

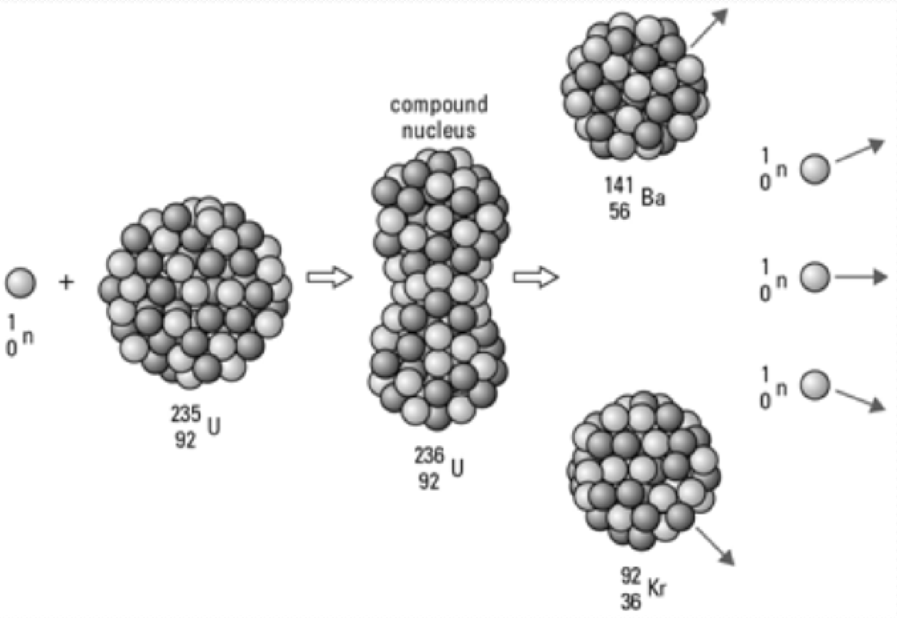
[redacted]

What type of radiation is this?



Nuclear Fission

- Radioactive decay is a natural process and will occur spontaneously
- Nuclei can be made to artificially decay by shooting a neutron at it in a process called **nuclear fission**

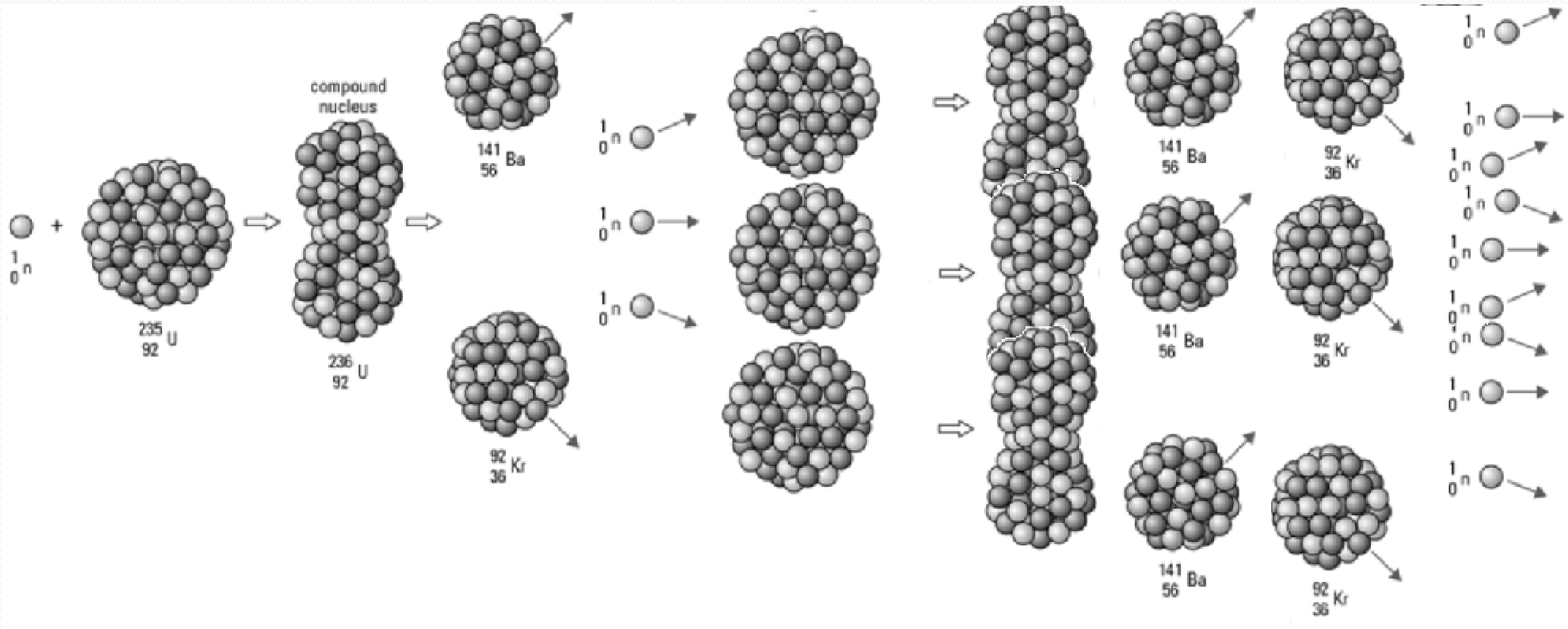


Nuclear **Fission**

$$ {}^{1}_{0}n + {}^{235}_{92}U \longrightarrow {}^{140}_{56}Ba + {}^{92}_{36}Kr + {}^{1}_{0}n + {}^{1}_{0}n + {}^{1}_{0}n $$

- Nuclear fission breaks large atoms up into smaller ones and in the process releases energy
- During the process three more neutrons are released which are able to collide
- This creates a chain reaction which will explode uncontrollably

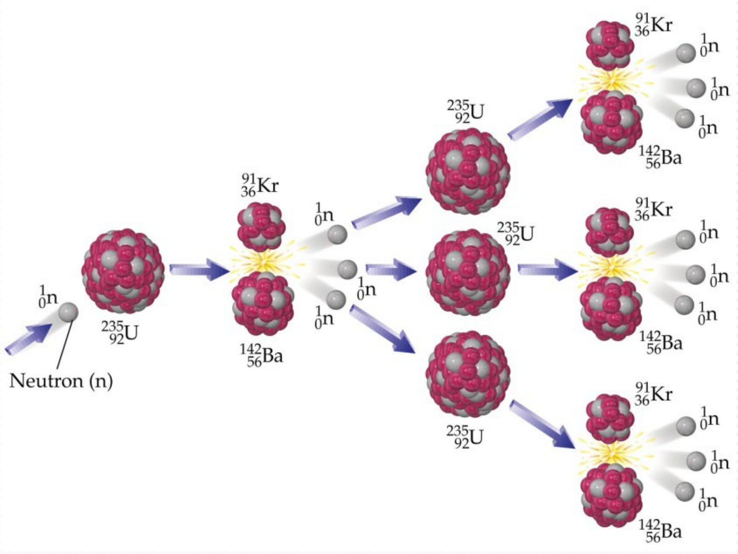
Chain Reaction



1) Balancing equations

- Same as the steps to balance all other types of radiation.
- Complete the following:

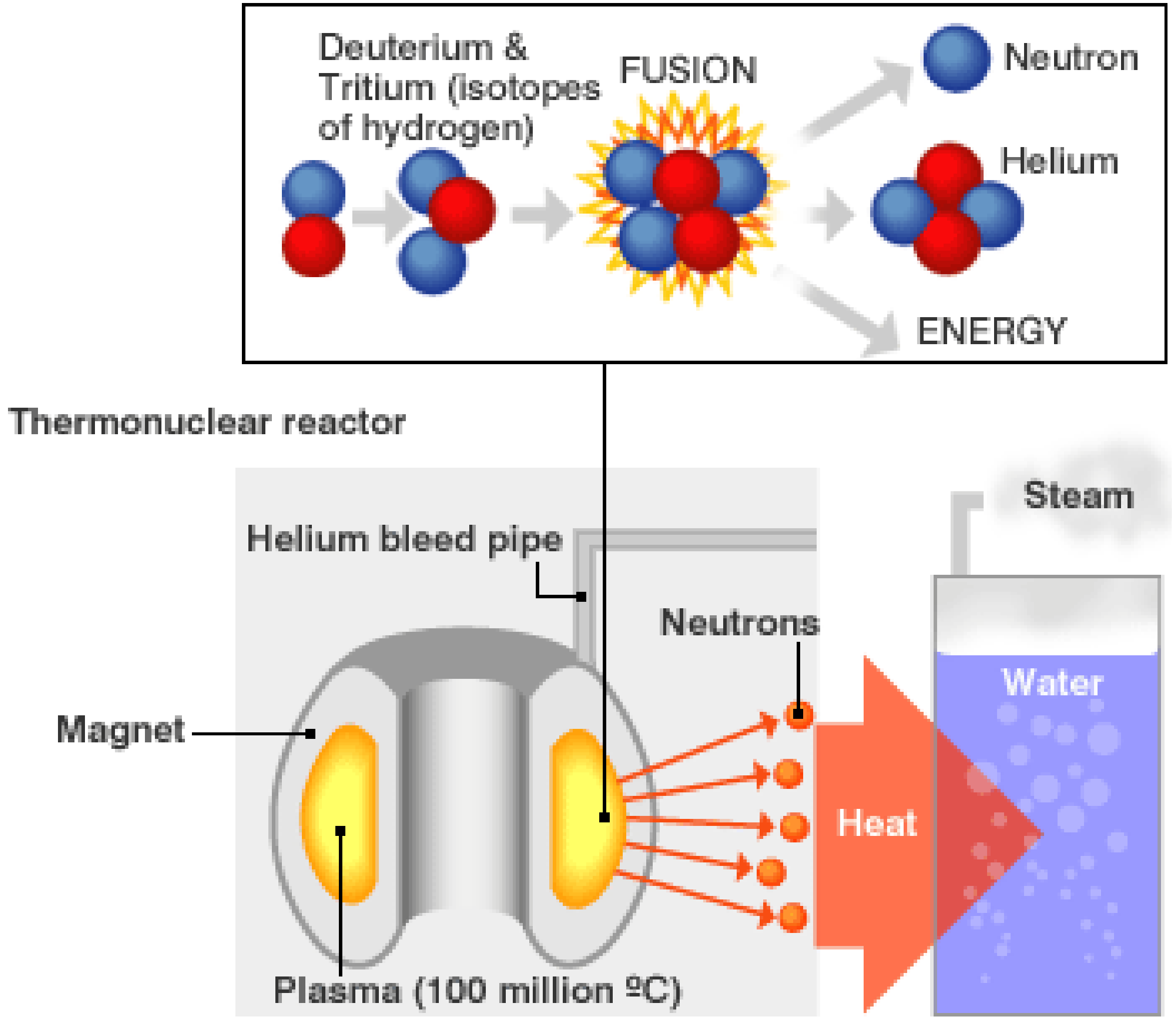
$$^{235}_{92}U + {}^{1}_{0}n \text{ ---> } 3\ {}^{1}_{0}n + {}^{A}_{Z}X + {}^{137}_{53}I$$



Nuclear **Fusion**

- energy of stars
- 2 **small masses combine** to form larger masses
- Extremely high temperature s required, so fusion reactions are called thermonuclear
- Slow controlled release of energy from a fusion reaction escapes physicists.
  - Has been pursued for over 40 years
  - Enormous potential energy and the fuel for this type of reaction is almost unlimited.

NUCLEAR FUSION



$E=mc^2$

- When water changes to a gas, what type of reaction is it?
- When gasoline burns, what type of reaction is it?
- $E=mc^2$ show what happens if instead of reacting chemically, the mass is converted into pure energy
- E = change in energy (J)
- m = change in mass (kg)
- c = speed of light (3.00×10^8 m/s)

Example

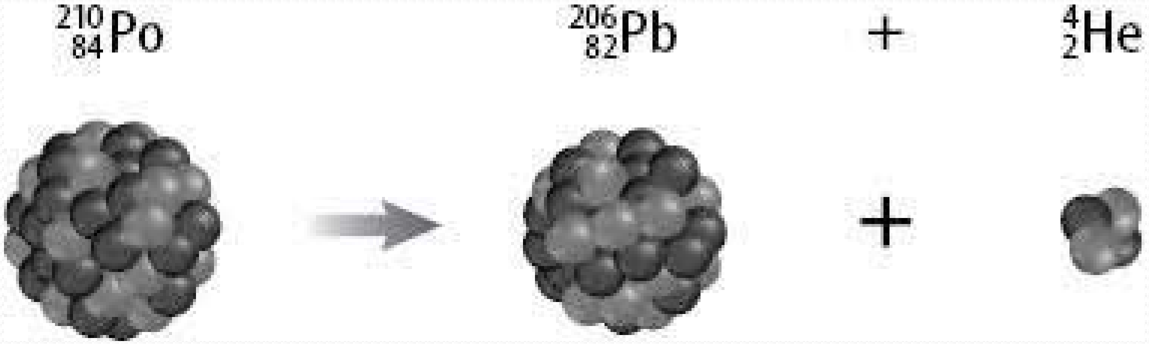
- What is the equivalent energy in a liter of gasoline if its mass (0.954 kg) is completely converted to pure energy by Einstein's equation $E = mc^2$.

Example

- The production of free neutrons cause an uncontrollable release of energy which lead to the first atomic bomb
- Using page 8 of your data booklet, determine the amount of energy released from the reaction:

$$ {}^{1}_{0}n + {}^{236}_{92}U \rightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + {}^{1}_{0}n + {}^{1}_{0}n + {}^{1}_{0}n $$

Find the energy released from this reaction



Step 1: find the difference in mass
Step 2: $E = mc^2$

6.156×10^{11} J

If product is less than reactants = exothermic

If reactants are more than products = endothermic

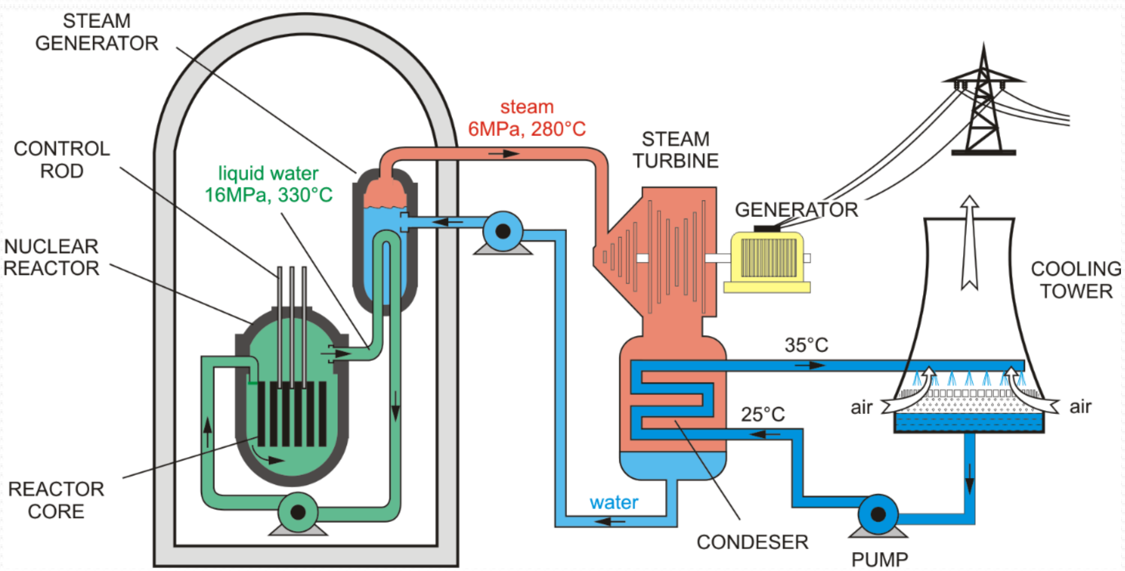
Board Question

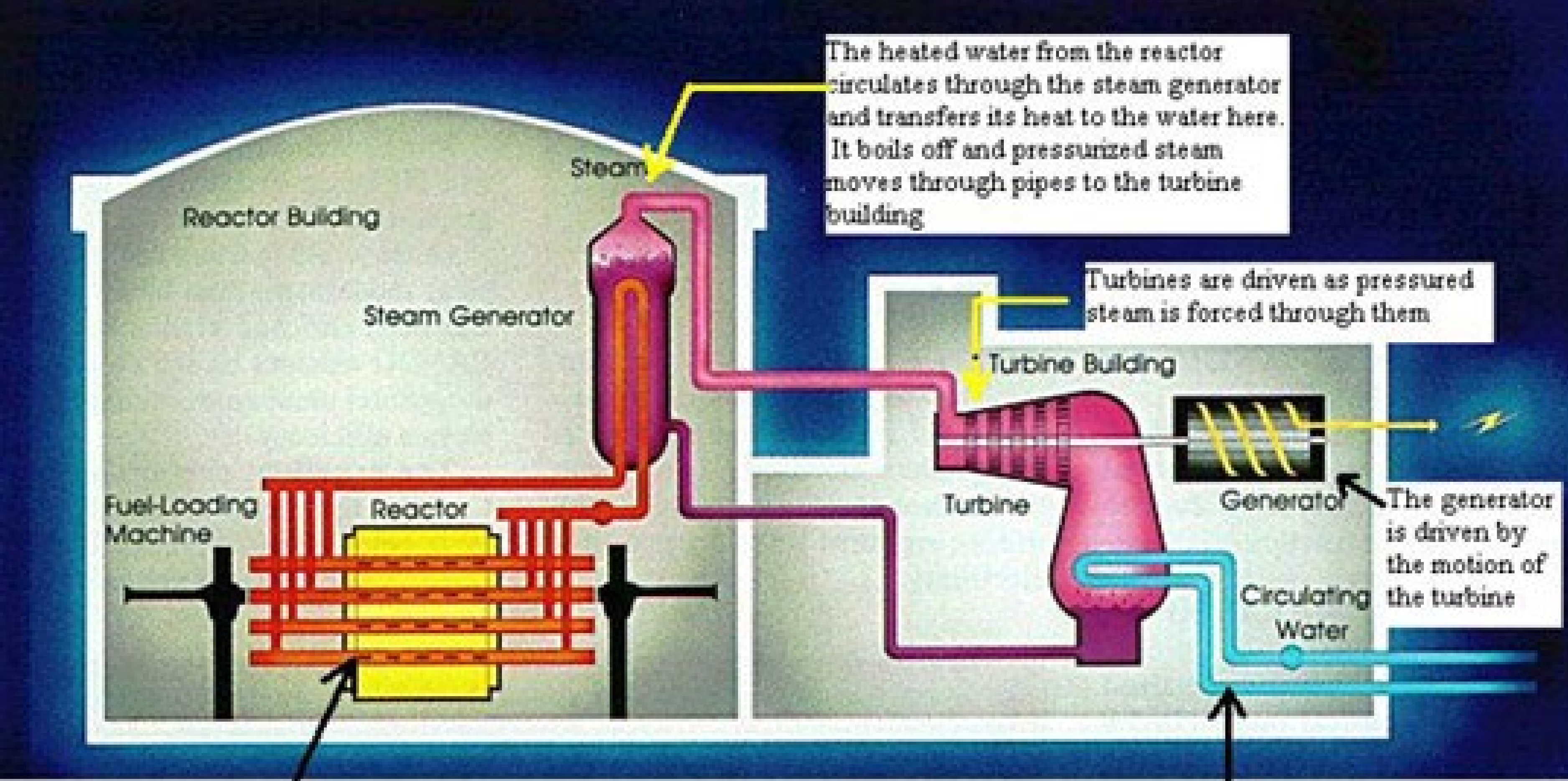
- In the fission of 1 mol of beryllium-8, the mass of the products is determined to be 2.29×10^{-5} kg less than the mass of the reactants. Calculate the change in energy that corresponds with this change in mass. Identify whether this reaction is exothermic or endothermic.

CANDU

$${}^{1}_{0}n + {}^{236}_{92}U \rightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + {}^{1}_{0}n + {}^{1}_{0}n + {}^{1}_{0}n$$

- In the CANDU (CANadian Deuterium Uranium) reactor, is the main type of nuclear reactor used around the world
- CANDU reactors run on uranium fuel rods
- Cadmium rods absorb neutrons to slow reaction



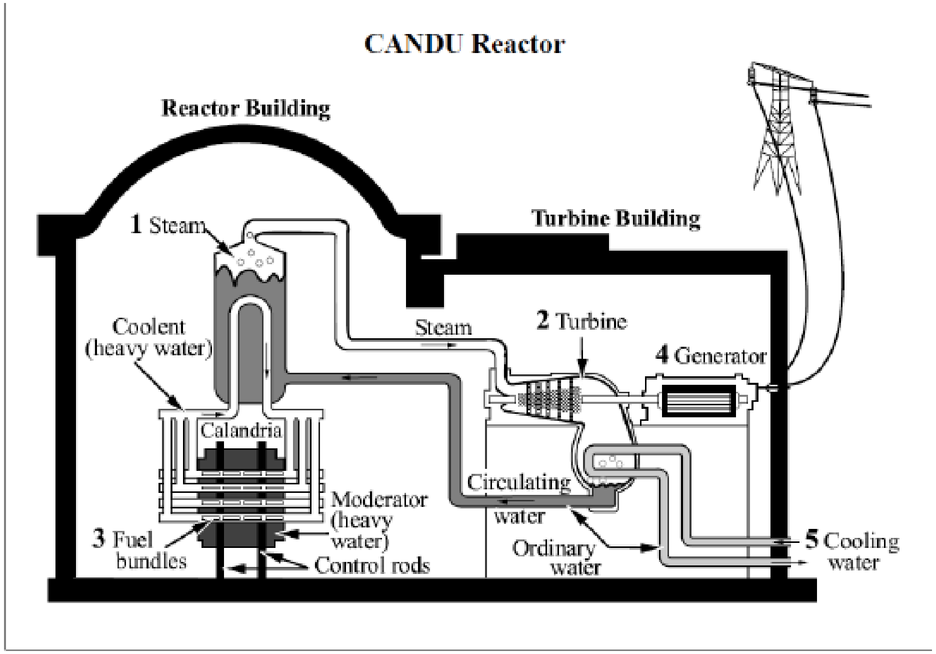


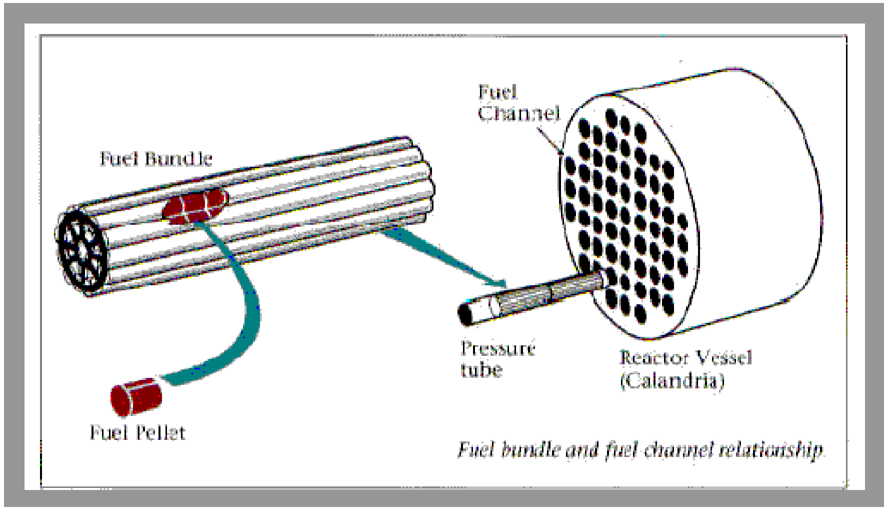
Reactor contains U-235 with heavy water moderator. Heat energy from nuclear reactions is carried away by the heavy water (water molecules with deuterium atoms) from the core under pressure to the steam generator.

Circulating water from an external source (lake) is used to absorb the heat from the steam. This cools it and condenses it to be pumped back into the steam generator. An undesired side effect is thermal pollution of the lake as the now warm circulating water is pumped back.

Canada's CANDU Reactor

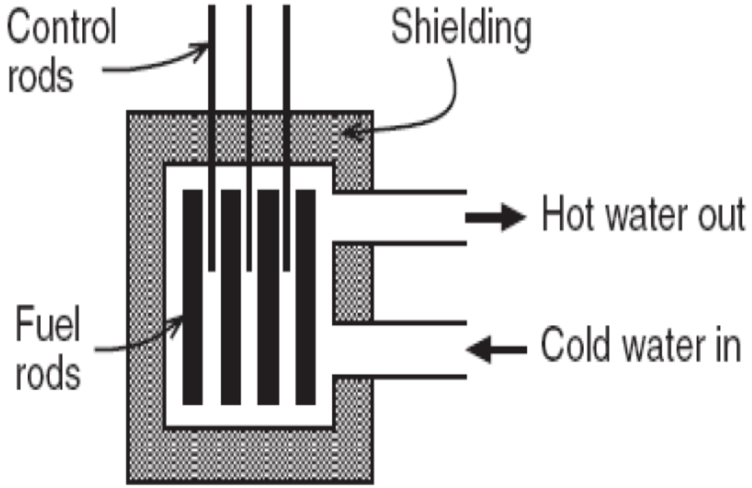
- Canadian Deuterium Uranium Reactor





Fuel bundle and fuel channel relationship.

CANDU

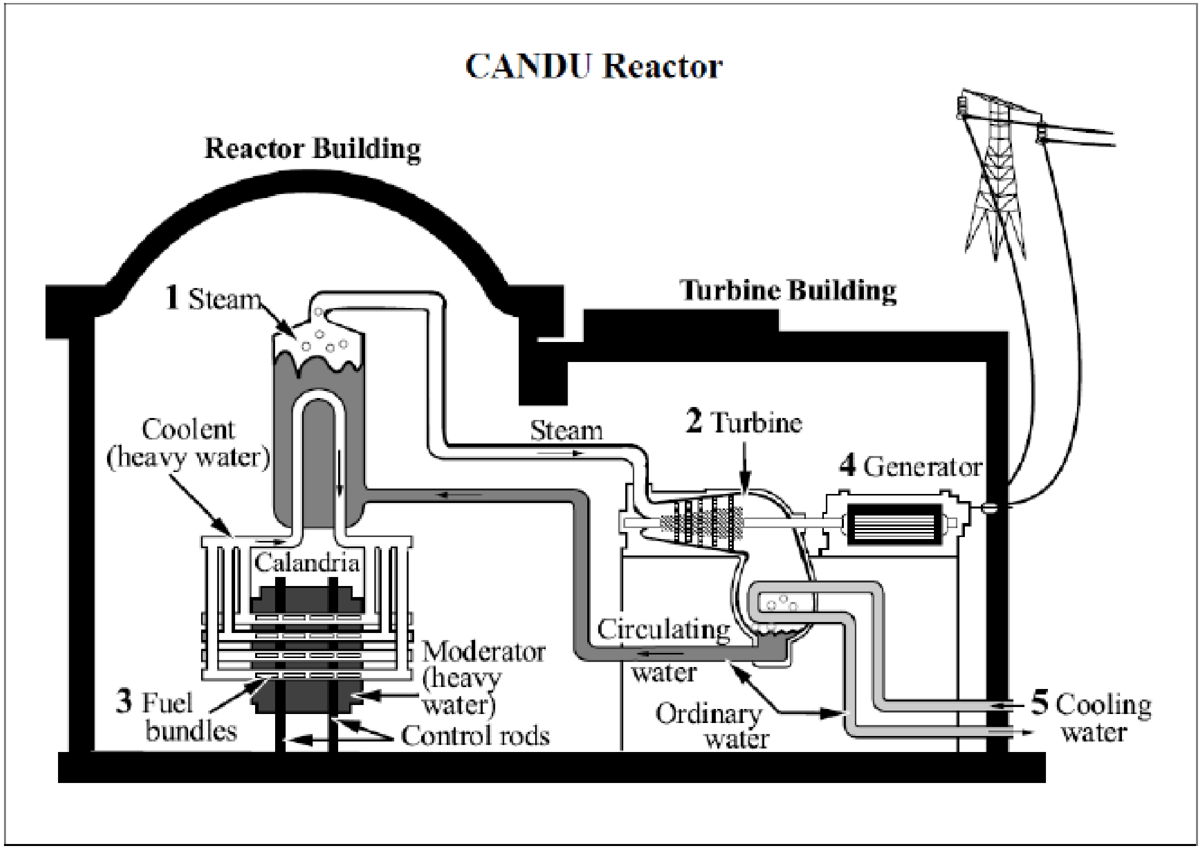


- control rods absorb neutrons
- If there are no free neutrons, the fission reactions stop

- Heavy water is water where the hydrogen atoms have 1 neutron

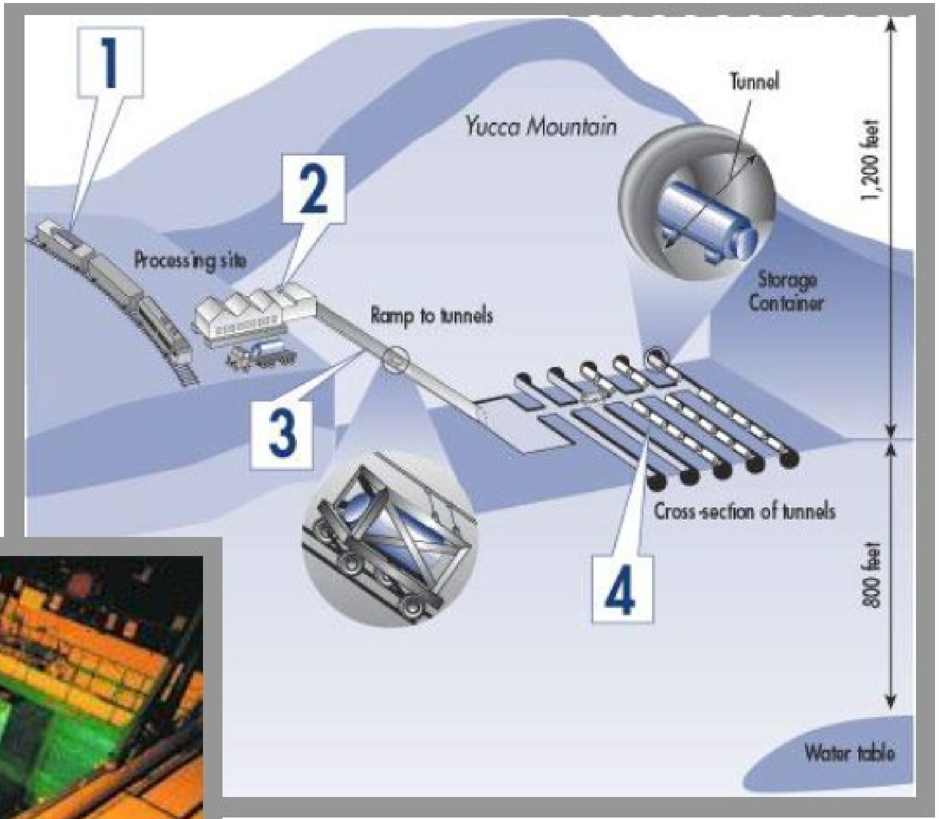
$$^{2}_{1}H$$

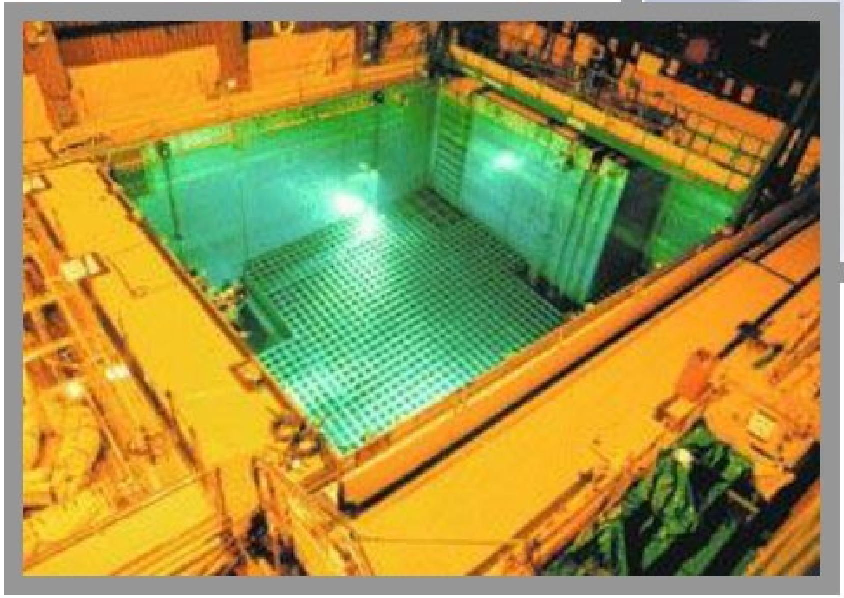
- The heavy water is a moderator, it slows the neutrons that are released in fission
- Only slow neutrons can cause fission



- Heat from fission heats heavy water which is then pumped under pressure to boil normal water

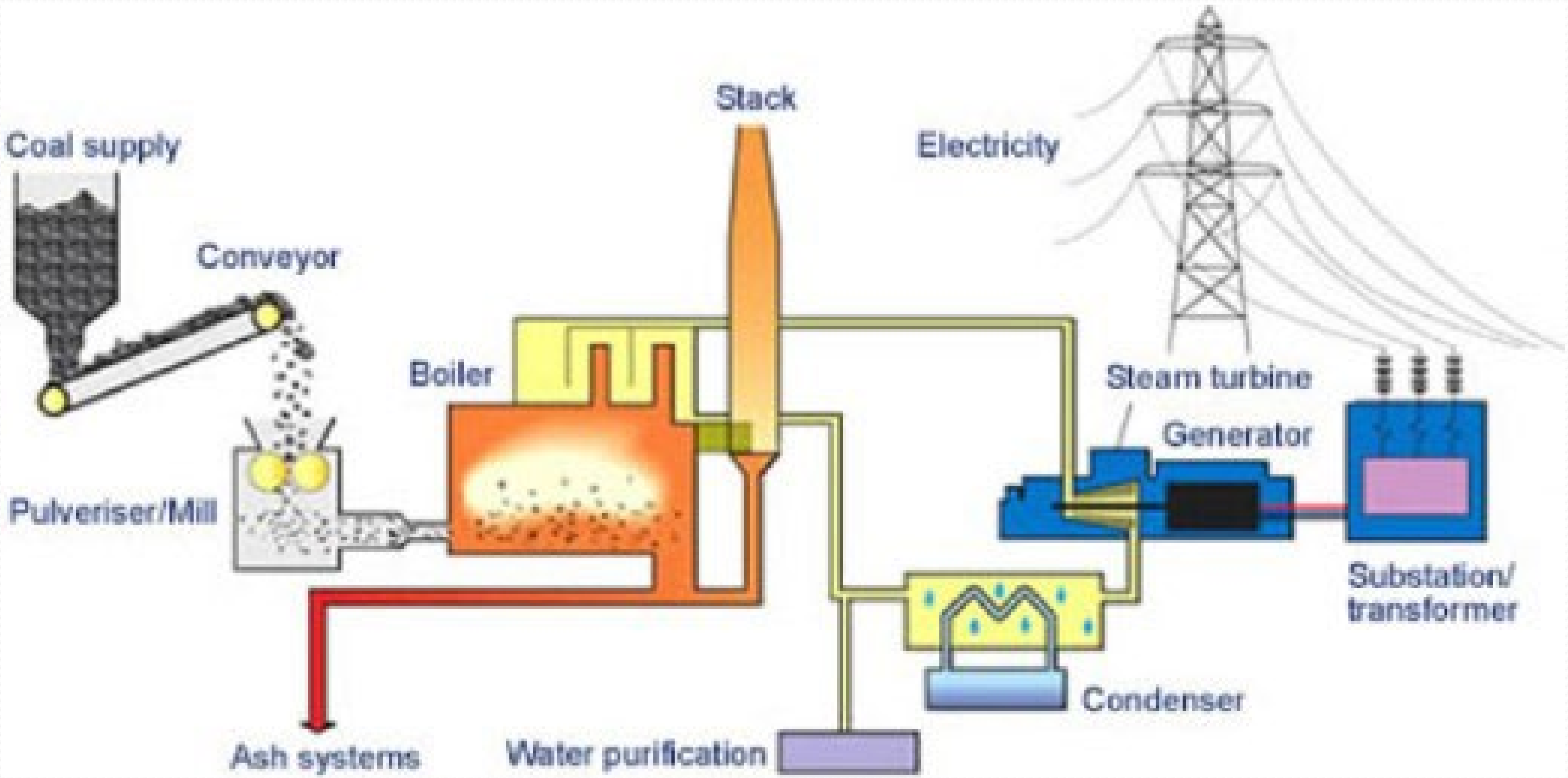
• There is a lot of radiation released inside nuclear reactors and by the spent fuel *(but still less than is emitted by x-ray machines)*





• Some coal-fired power plants emit more radioactivity than nuclear plants (uranium in coal ash)

Fossil Fuel Power Plant



Nuclear vs. Fossil Fuel

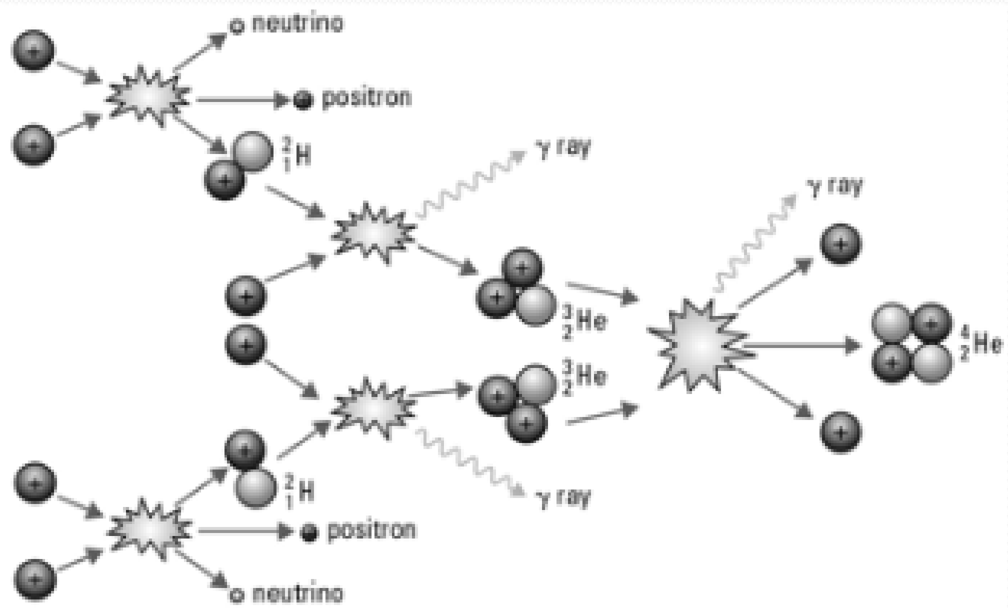
similarities	differences

Castle Bravo

Castle Bravo

- Castle Bravo was a hydrogen or thermonuclear bomb that was detonated March 1, 1954 at Bikini Atoll, Marshall Islands
- In hydrogen or thermonuclear bomb, the same reaction which is created in the sun is reproduced
- To generate the large temperatures necessary, a nuclear fission bomb is placed inside the hydrogen bomb, and exploded first to produce the heat required
- The energy released by a thermonuclear fusion bomb is more than ten times the magnitude of fission bombs.

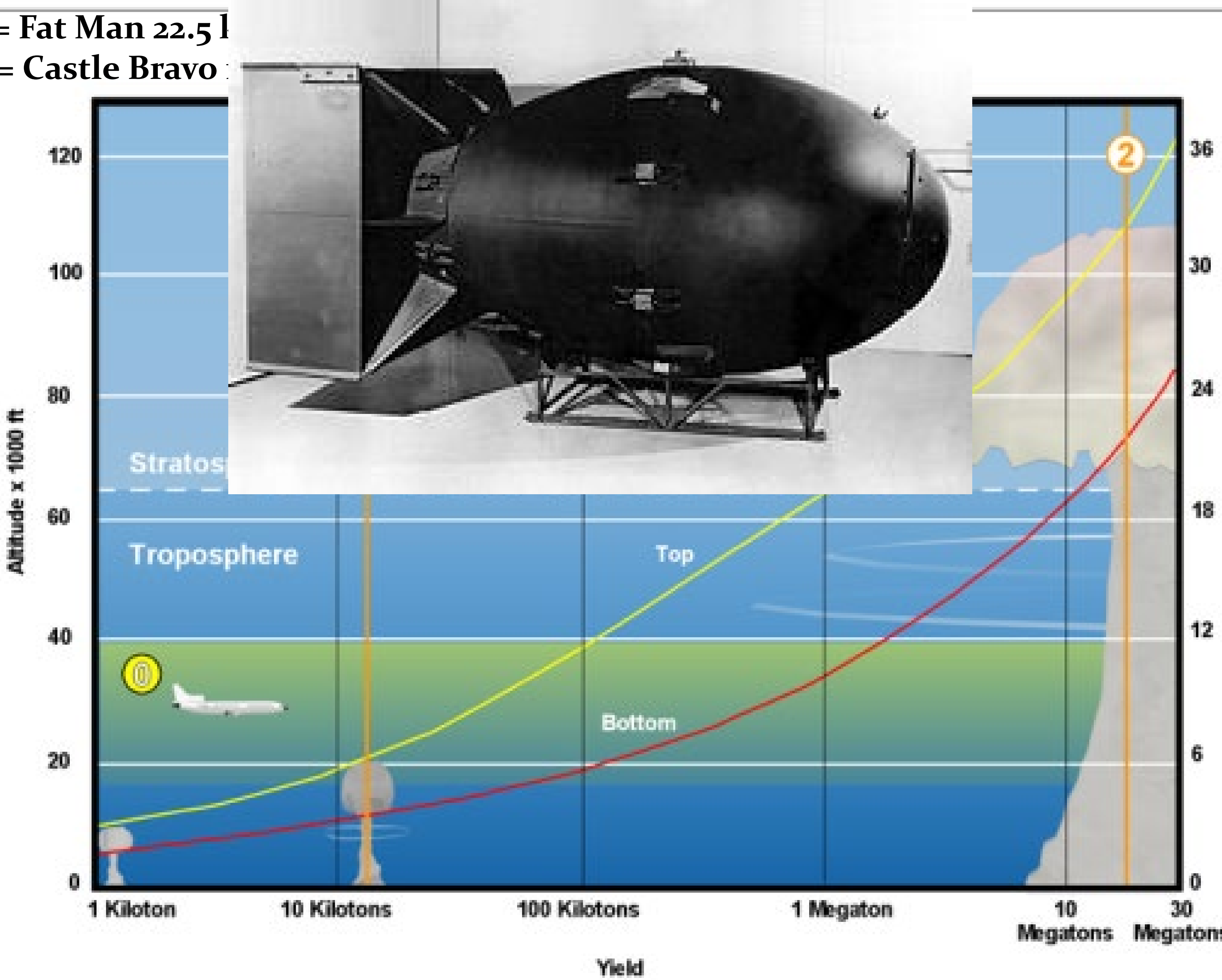
Fusion Reaction



Step	Reaction	Energy Released
1	$2\,^1_1\mathrm{H} \rightarrow {}^2_1\mathrm{H} + {}^0_1\beta + \nu$ (twice)	0.42 MeV (twice)
2	$^1_1\mathrm{H} + {}^2_1\mathrm{H} \rightarrow {}^3_2\mathrm{He} + \gamma$ (twice)	5.49 MeV (twice)
3	$2\,^3_2\mathrm{He} \rightarrow {}^4_2\mathrm{He} + 2\,^1_1\mathrm{H} + \gamma$	12.85 MeV
Total	$4\,^1_1\mathrm{H} \rightarrow {}^4_2\mathrm{He} + 2\,^0_1\beta + 2\nu + 3\gamma$	24.67 MeV

1 = Fat Man 22.5

2 = Castle Bravo



UNLIMITED POWER!!!

- With hydrogen in plentiful supply here on earth, fusion could theoretically supply virtually an unlimited energy source for mankind
- Why don't we use it then?

- Research is on to use magnetic fields to confine the hydrogen
- The products of fusion (helium) are a lot safer than the nuclear waste fission produces