These notes are posted on my site for the following reasons:

- for students to copy in their own hand-writing
  - in order to complete their class notes
  - if student did not have enough time in class
  - if student was away and missed this section
- for assistants and tutors to follow progress of the concepts taught

Photocopied/printed notes can not be used during the Unit Notebook Check in class.

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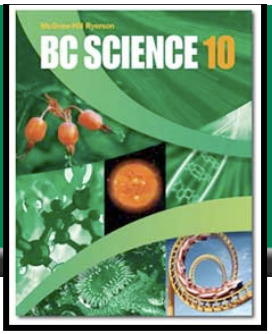
7.3 Nuclear Reactions

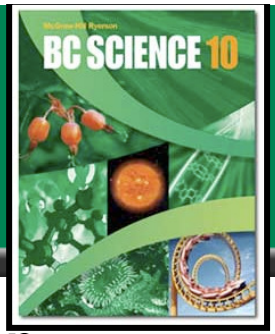


- **Nuclear fission and fusion are processes that involve extremely large amounts of energy.**
  - **Fission = the splitting of nuclei**
  - **Fusion = the joining of nuclei**
- **Nuclear power plants can generate large amounts of electricity.**
  - **In Canada, Ontario, Quebec and New Brunswick currently use nuclear power.**
  - **Canadian-made nuclear reactors are called CANDU reactors.**
    - **CANDU reactors are considered safe and effective, and are sold throughout the world.**

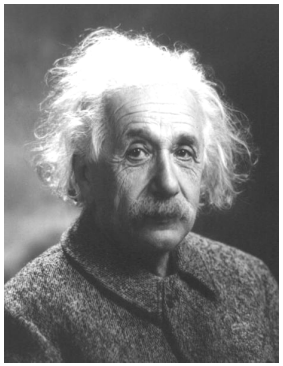
The Bruce Nuclear Generating Station on the shores of Lake Huron, in Ontario

See page 312

Nuclear Fission



- **Nuclear energy used to produce power comes from fission.**
  - Nuclear fission is the splitting of one heavy nucleus into two or more smaller nuclei, as well as some sub-atomic particles and energy.
  - A heavy nucleus is usually unstable, due to many + protons pushing apart.
  - When fission occurs:
    1. Energy is produced.
    2. More neutrons are produced.

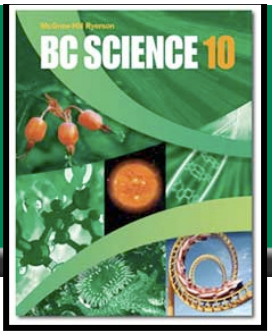


Albert Einstein's equation $E = mc^2$ illustrates the energy found in even small amounts of matter

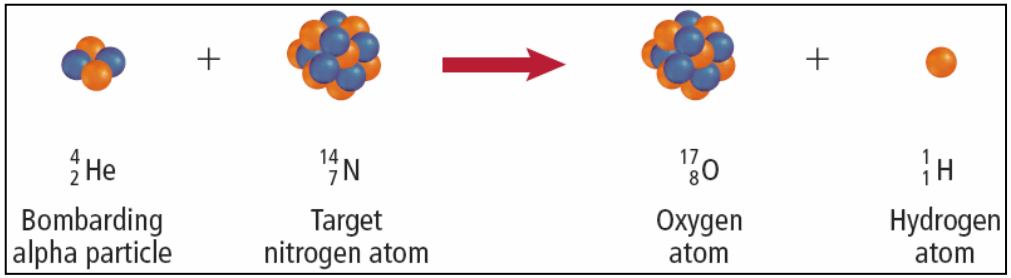
- **Nuclear reactions are different than chemical reactions.**
  - In chemical reactions, mass is conserved, energy changes are relatively small.
    - There are no changes to the nuclei in chemical reactions
  - In nuclear reactions, the actual nucleus of atoms changes.
    - Protons, neutrons, electrons and/or gamma rays can be lost or gained.
    - Small changes of mass = huge changes in energy

See pages 313 - 314

Nuclear Equations for Induced Nuclear Reactions



- **Natural radioactive decay consists of the release of alpha, beta and gamma radiation.**
  - **Scientists can also force (= induce) nuclear reactions by smashing nuclei with alpha, beta and gamma radiation.**



$$^{4}_{2}\alpha + {}^{14}_{7}\mathrm{N} \rightarrow {}^{17}_{8}\mathrm{O} + {}^{1}_{1}p$$

or

$$^{4}_{2}\mathrm{He} + {}^{14}_{7}\mathrm{N} \rightarrow {}^{17}_{8}\mathrm{O} + {}^{1}_{1}\mathrm{H}$$

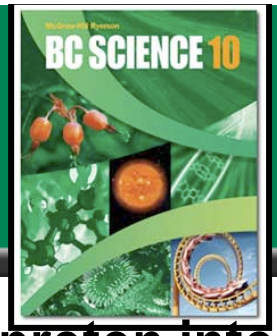
  - **The rules for writing these equations are the same as earlier nuclear equations**
    - **Mass numbers must equal on both sides of the equation**
    - **Charges must equal on both sides of the equation**

Table 7.9 Subatomic particles in nuclear reactions

Particle (symbol)	Also known as
proton ($^{1}_{1}p$)	hydrogen-1 nucleus ($^{1}_{1}$H)
neutron ($^{1}_{0}n$)	---
helium nucleus ($^{4}_{2}$He)	alpha particle ($^{4}_{2}\alpha$)
electron ($^{0}_{-1}e$)	beta particle ($^{0}_{-1}\beta$)

See pages 314 - 315

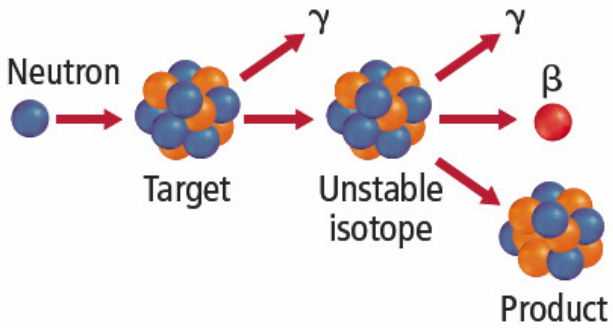
Nuclear Fission of Uranium-235



- **It is much easier to crash neutral neutron than a positive proton into a nucleus to release energy.**
  - **Most nuclear fission reactors and weapons use this principle.**
  - **A neutron, ${}^{1}_{0}n$, crashes into an atom of stable uranium-235 to create unstable uranium-236, which then undergoes radioactive decay.**
  - **After several steps, atoms of krypton and barium are formed, along with the release of 3 neutrons and huge quantities of energy.**

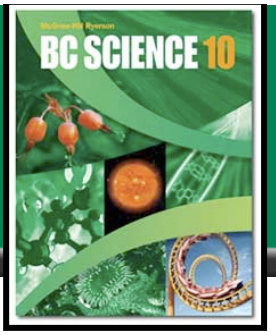
The induced nuclear fission of uranium-235. This nuclear reaction is the origin of nuclear power and nuclear bombs.

$$ {}^{1}_{0}n + {}^{235}_{92}\mathrm{U} \rightarrow {}^{92}_{36}\mathrm{Kr} + {}^{141}_{56}\mathrm{Ba} + 3\ {}^{1}_{0}n + \text{energy} $$

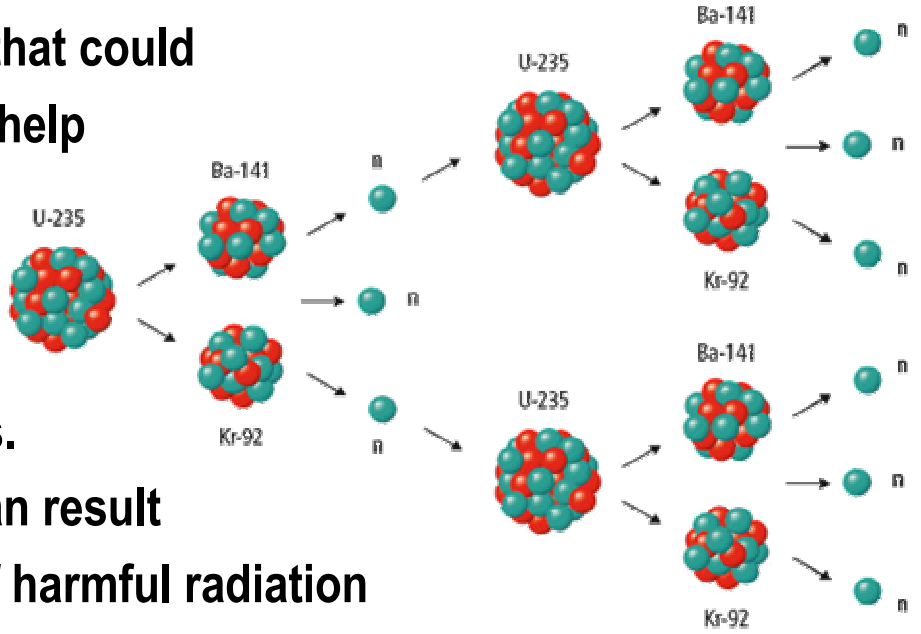


See pages 316 - 317

Chain Reactions

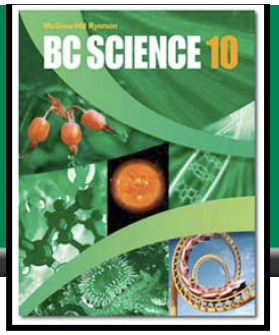


- **Once the nuclear fission reaction has started, it can keep going.**
  - The neutrons released in the induced reaction can then trigger more reactions on other uranium-235 atoms.
  - This chain reaction can quickly get out of control
    - Fermi realized that materials that could absorb some neutrons could help to control the chain reaction.
  - Nuclear reactors have complex systems to ensure the chain reaction stays at safe levels.
  - An uncontrolled chain reaction can result in the release of excess energy of harmful radiation
    - It is on this concept that nuclear bombs are created.

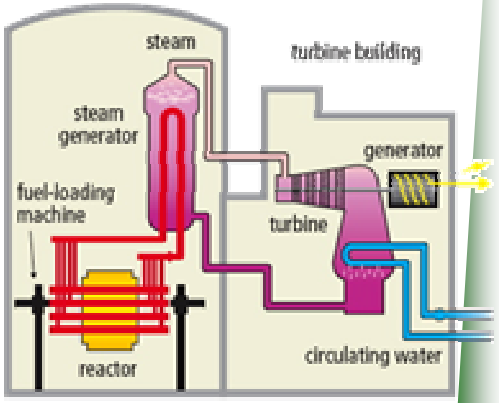


See page 318

CANDU Reactors and Hazardous Wastes



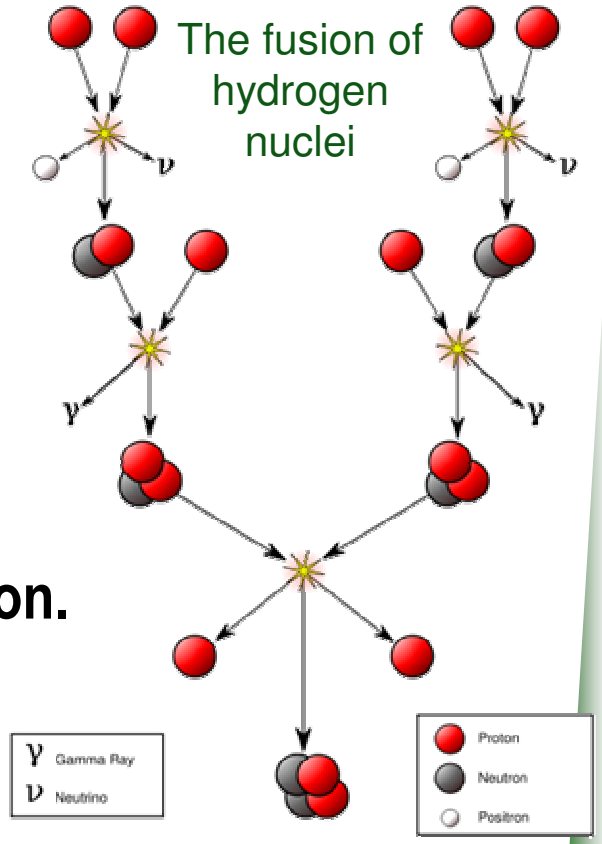
- **Canada's nuclear research into the safe use of nuclear reactions has resulted in the creation of CANDU reactors.**
  - CANDU rectors are found in various countries around the world.
    - Canada, South Korea, China, India, Argentina, Romania and Pakistan
  - The reactors are known to be safe and easy to shut down in an emergency.
    - Heat energy produced turns electricity-generating turbines.
- **Hazardous wastes produced by nuclear reactions are problematic.**
  - Some waste products, like fuel rods, can be re-used
  - Some products are very radioactive, however, and must be stored away from living things.
    - Most of this waste is buried underground, or stored in concrete
    - It takes 20 half-lives (thousands of years) before the material is safe.



See pages 319 - 320

Nuclear Fusion

- **Nuclear fusion = joining of two light nuclei into one heavier nucleus.**
  - **In the core of the Sun, two hydrogen nuclei join under tremendous heat and pressure to form a helium nucleus.**
  - **When the helium atom is formed, huge amounts of energy are released.**
    - $^{2}_{1}\mathrm{H} + {}^{3}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{1}_{0}n + \text{energy}$
- **Scientists cannot yet find a safe, manageable method to harness the energy of nuclear fusion.**
  - **So-called "cold fusion" would occur at temperatures and pressures that could be controlled.**



See pages 320 - 321

Take the Section 7.3 Quiz