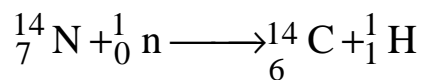


Ch 19 Nuclear Reactions

Nuclear reaction:



Atomic number: 左: $7 + 0$ 右: $6 + 1$
 mass number: 左: $14 + 1$ 右: $14 + 1$

§ 19-3 Mass-energy Reactions:

$$\Delta E = C^2 \cdot \Delta m$$

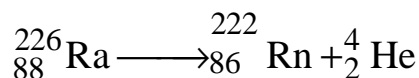
$$= (3.00 \times 10^8)^2 \frac{\text{m}^2}{\text{s}^2} \cdot \Delta m \quad 1\text{J} = 1\text{kg} \cdot \frac{\text{m}^2}{\text{s}^2}$$

$$\Delta E = 9.00 \times 10^{16} \frac{\text{J}}{\text{kg}} \cdot \Delta m \quad \therefore 1 \frac{\text{m}^2}{\text{s}^2} = 1 \frac{\text{J}}{\text{kg}}$$

$$= 9.00 \times 10^{16} \frac{\text{J}}{\text{kg}} \cdot \frac{\text{kg}}{10^3 \text{g}} \cdot \frac{\text{kJ}}{10^3 \text{J}} \cdot \Delta m$$

$$\therefore \Delta E = 9.00 \times 10^{10} \frac{\text{kJ}}{\text{g}} \cdot \Delta m$$

Ex 19-4: For the radioactive decay of radium



Calculate ΔE in kJ when 10.2g of radium decays?

Ans:

$$\Delta m = m_{\text{He}} + m_{\text{Rn}} - m_{\text{Ra}}$$

$$\Delta m = (4.0015 + 221.9703) - 225.9771$$

$$= -0.0053 \frac{\text{g}}{\text{mole} \cdot \text{Ra}}$$

$$10.2 : 225.9771 = x : -0.0053$$

$$x = -2.4 \times 10^{-4} \text{g}$$

$$\Delta E = 9.00 \times 10^{10} \cdot \Delta m$$

$$= 9.00 \times 10^{10} \cdot (-2.4 \times 10^{-4})$$

$$= -2.2 \times 10^7 \text{kJ}$$

the energy is much greater than ordinary chemical reactions.

§ 19-4 Nuclear Fusion 核分裂

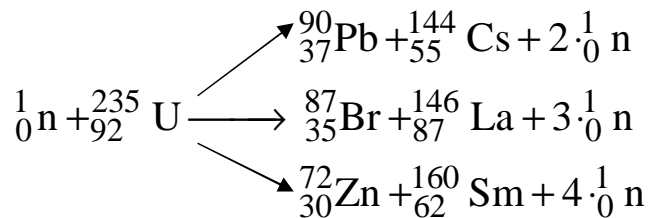
Attention has centered on two particular isotopes, ${}_{92}^{235}\text{U}$ and ${}_{94}^{239}\text{Pu}$

Both of those can be split into fragments by relatively low-energy neutron.

${}_{92}^{235}\text{U}$ is only about 0.7% of naturally occurring Uranium.

To separate the isotopes by gaseous effusion (Ch5). The volatile compound UF_6 , which sublimates at 56°C , is used for gaseous effusion.

§ ${}_{92}^{235}\text{U}$ Fission Process:



More than 200 isotopes of 35 different elements have been identified among the fission products of ${}_{92}^{235}\text{U}$

One a few atoms of ${}_{92}^{235}\text{U}$ split, the neutrons produced can bring about the fission of many more ${}_{92}^{235}\text{U}$ atoms.

↓

A chain reaction, whose rate increases exponentially with time.

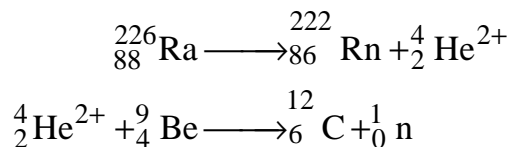
↓

The energy evolved in successive fission escalated to give a tremendous explosion within a few seconds.

The evolution of energy in nuclear fission is directly related to the decrease in mass that place. About 80,000,000kJ of energy is given off every grams of ${}_{92}^{235}\text{U}$ that reacts, which is equal to the combustion of 2700kg of coal or the explosion of 30 metric tons of TNT.

§ Nuclear Reactor --- Light water reactor

1. 以 ${}_{92}^{235}\text{U}$ 為原料，一般採用 ${}_{92}^{235}\text{U} + \text{Zr}$ 合金
2. 中子源: Ra-Be 合金

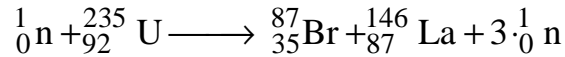


3.重水(D₂O) or 石墨為中子減速劑

∴ fast neutrons are not readily absorbed by U-235.

4.Cd or B 與鋼之合金棒為控制棒 ⇒ 吸收過多中子

5.核反應:



6.Pb 防護板外加厚水泥牆

7.核分裂產生之熱以水為冷卻劑 ⇒ 發電

Figure 19.5

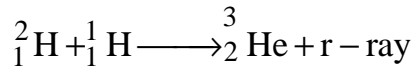
A pressurized water nuclear reactor. The control rods are made of a material such as cadmium or boron, which absorbs neutrons effectively. The fuel rods contain uranium oxide enriched in U-235.

Thirty years ago it was generally supposed that nuclear fission would replace fossil (oil, natural gas, coal), but it hasn't happened for three reasons:

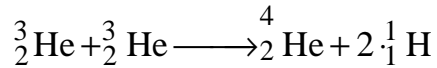
1. Nuclear energy is more expensive; nuclear 7 ¢ / kw · h
fossil fuels 3 ¢ / kw · h
2. Nuclear accidents Three Mile Island and Chernobyl.
3. Disposal of radioactive wastes; “NIHBY” not in my back yard.

↓

解決: PEEK 儲存槽



§ 19-5 Nuclear Fusion 核融合

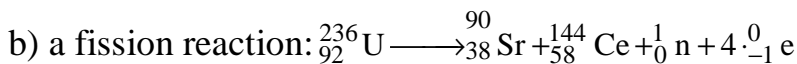
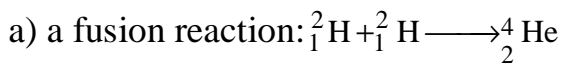


Very light nuclei, such as those of hydrogen, are unstable with respect to fusion into heavier isotopes.

↓

generate greater energy than that given off in the fission of equal mass of heavy element.

Ex 19-6: Calculate ΔE in kJ per gram of reactants in



Ans: eq. (19-3) $\Delta E = 9.00 \times 10^{10} \text{ kJ/g} \cdot \Delta m$

a) $\Delta m = 4.00150 - 2 \cdot (2.01355) = -0.02560 \text{ g}$

$$-0.02560 : 4.027 = x : 1$$

$$x = -6.357 \times 10^{-3} \text{ g/g reactant}$$

$$\Delta E = 9.00 \times 10^{10} \cdot (6.357) \times 10^{-3}$$

$$= -5.72 \times 10^8 \text{ kJ/g reactant}$$

b) $\Delta m = 89.8869 + 143.8817 + 1.0087 + 4 \cdot (0.00055) - 234.9934$

$$= -0.213 \text{ g}$$

$$-0.213 : 234.9934 = x : 1$$

$$x = 9.102 \times 10^{-4} \text{ g/g reactant}$$

$$\Delta E = 9.00 \times 10^{10} \cdot 9.102 \times 10^{-4}$$

$$= -8.19 \times 10^7 \text{ kJ/g reactant}$$

\therefore nuclear fusion gives off more energy.

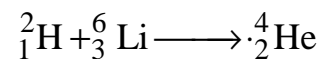
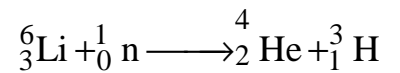
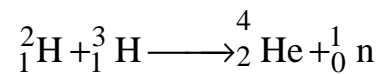
Nuclear fusion 與 nuclear 比較:

- 優: 1. light isotopes suitable for fusion are far more abundant than the heavy isotopes required for fission.
2. Create more energy
3. No nuclear waste

缺: Nuclear fusion processes have high activation energies, the corresponding temperature for fusion is of the order of 10^9 °C

未來發展:

1. new process:



it has lower activation energy than other fusion reactions.

- (1) achieve a net evolution of energy
2. Using 400-ton magnets (2) Creates magnetic fields to confine the reactant nuclei and prevent them from touching the walls of the container.
3. Tiny glass pellets (D = 0.1 mm) filled with deuterium and tritium serve as a target. The pellets are illuminated by a powerful laser beam, which delivers 10^{12} kw of power in 10^{-9} s.

⇓

this point energy breakeven seems many years away.