Ch 19 Nuclear Reactions

Nuclear reaction:

$$^{14}_{7}N + ^{1}_{0}n \longrightarrow ^{14}_{6}C + ^{1}_{1}H$$

Atomic number: 左: 7 + 0 右: 6 + 1

mass number: 左: 14 + 1 右: 14 + 1

§ 19-3 Mass-energy Reactions:

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

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

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

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

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

Ex 19-4: For the radioactive decay of radium

$$^{226}_{88}Ra \longrightarrow ^{222}_{86}Rn + ^{4}_{2}He$$

Calculate ΔE in kJ when 10.2g of radium decays?

Ans:

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

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

$$= -0.0053\, g/mole \cdot Ra$$

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

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

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

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

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

the energy is much greater than ordinary chemical reactions.

§ 19-4 Nuclear Fusion 核分裂

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

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

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

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

§ ^{235}U Fusion Process:

$$^{1}_{0}n + ^{235}_{92}U \longrightarrow \begin{cases} ^{90}_{37}Pb + ^{144}_{55}Cs + 2\cdot ^{1}_{0}n \\ ^{87}_{35}Br + ^{146}_{87}La + 3\cdot ^{1}_{0}n \\ ^{72}_{30}Zn + ^{160}_{62}Sm + 4\cdot ^{1}_{0}n \end{cases}$$

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

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

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A chain reaction, whose rate increases exponentially with time.

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

$$^{226}_{88}Ra \longrightarrow ^{222}_{86}Rn + ^{4}_{2}He^{2+}$$

$$^{4}_{2}He^{2+} + ^{9}_{4}Be \longrightarrow ^{12}_{6}C + ^{1}_{0}n$$

3.重水(D_2O) or 石墨爲中子減速劑

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

4.Cd or B 與鋼之合金棒爲控制棒⇒吸收過多中子

5.核反應:

$$ {}_{0}^{1}n + {}_{92}^{235}U \longrightarrow {}_{35}^{87}Br + {}_{87}^{146}La + 3\cdot{}_{0}^{1}n $$

6.Pb 防護板外加厚水泥牆

7.核分裂產生之熱以水爲冷卻劑⇒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 $7¢/kw\cdot h$

   fossil fuels $3¢/kw\cdot h$

2. Nuclear accients Three Mile Island and Chernobyl.
3. Disposal of radioactive wastes; "NIHBY" not in my back yard.

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解決: PEEK 儲存槽

$${}^{2}_{1}H + {}^{1}_{1}H \longrightarrow {}^{3}_{2}He + r - ray$$

§ 19-5 Nuclear Fusion 核融合

$${}^{3}_{2}He + {}^{3}_{2}He \longrightarrow {}^{4}_{2}He + 2 \cdot {}^{1}_{1}H$$

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

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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

a) a fusion reaction: ${}^{2}_{1}H + {}^{2}_{1}H \longrightarrow {}^{4}_{2}He$

b) a fission reaction: ${}^{236}_{92}U \longrightarrow {}^{90}_{38}Sr + {}^{144}_{58}Ce + {}^{1}_{0}n + 4 \cdot {}^{0}_{-1}e$

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

a) $\Delta m = 4.00150 - 2 \cdot (201355) = -0.02560g$

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

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

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

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

b)

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

$$= -0.213g$$

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

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

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

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

∴ 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. Creat 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:

$$
\begin{array}{l}
{}^{2}_{1}H + {}^{3}_{1}H \longrightarrow {}^{4}_{2}He + {}^{1}_{0}n \\
{}^{6}_{3}Li + {}^{1}_{0}n \longrightarrow {}^{4}_{2}He + {}^{3}_{1}H \\
\hline
{}^{2}_{1}H + {}^{6}_{3}Li \longrightarrow \cdot {}^{4}_{2}He
\end{array}
$$

it has lower activation energy than other fusion reactions.

2. Using 400-ton magnets (1) achieve a net evolution of energy (2) Creats magnetic fields to confine the reactant nuclei and prevent them from touching the wells 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.

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this point energy breakeven seems many years away.