Binding Energy and Mass Defect

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Every process that releases energy is accompanied by a loss of mass. → exothermic

Every process that absorbs energy is accompanied by a gain of mass. → endothermic

Chemical reactions → ΔM is too small to measure.

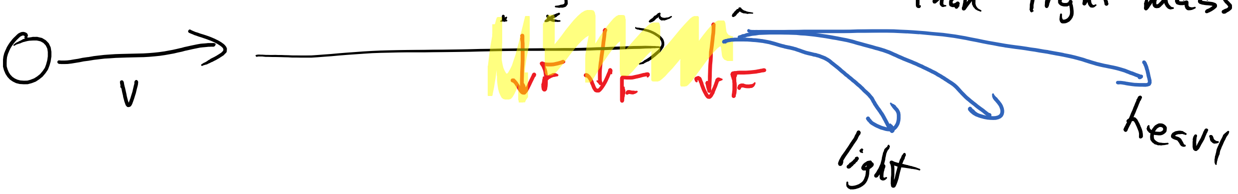
Nuclear Reactions → Δm is measurable with mass spectroscopy

A Mass Spectrometer:

① Shoot a sample down a tube.

② Passes through a strong eletric or magnetic field

③ Heavier masses are deflected less than light masses



$\#p^+ + \#n \longrightarrow$ nucleus Exothermic

Thus, the mass of the nucleus is smaller than the mass of the parts that made it.

We call this mass defect (Δm)

Δm = mass of $\#p^+$ + mass of $\#n$ − mass of the nucleus

We plug this into Einstein's $E=mc^2$ to find the binding energy.

For a single nucleus, most binding energies are ~ 10^{-10}–10^{-12} J. Binding energy per nucleon (nuclear particle) are $\sim 10^{-10} - 10^{-12}$ J. Binding energy per nucleon (nuclear particle n, p^+) is used to guage the stability of nuclei.

$$BEPN = \frac{\Delta E}{A}$$

ΔE ← Binding Energy

A ← mass number of the isotope.

The greater the binding energy per nucleon, the more stable the nucleus. ^{56}Fe ← the most stable in the universe!

Find the Binding Energy and BEPN for of Osmium-190.

$^{190}Os = 189.95863$ amu

How many $190-76=$ 114 $m_n = 1.008665$ amu

76 $m_p = 1.007276$ amu

$114 m_n + 76 m_p \rightarrow m_{Os} + \Delta m$

$114(1.008665) + 76(1.007276) = 189.95863 + \Delta m$

$114.98781 + 76.552976 = 189.95863 + \Delta m$

$\Delta m = 1.582156$ amu

1 amu = 931.49 MeV

Binding Energy →

$$\Delta E = 1.582156\,\cancel{\text{amu}} \times \frac{931.49\,\text{MeV}}{\cancel{1\,\text{amu}}} = \boxed{1473.8\,\text{MeV}}$$

$$BEPN = \frac{\Delta E}{A} = \frac{1473.8\,\text{MeV}}{190} = \boxed{7.7566\,\text{MeV}}$$

This can extend to nuclear reactions.

1. Calculate the energy released when 1 atom of ^{235}U under goes Fission to form ^{137}Te and ^{96}Zr.

$m\,^{235}U = 235.043915u$ $\quad$ $m_n = 1.008665$

$m\,^{137}Te = 136.925449u$

$m\,^{96}Zr = 95.908286u$

Step ① set up the nuclear equation

$$^{1}_{0}n + {}^{235}_{92}U \longrightarrow {}^{137}_{52}Te + {}^{96}_{40}Zr + 3\,{}^{1}_{0}n$$

Step ② Add up the masses

$$m_n + M^{235}U = m^{137}Te + m^{96}Zr + 3m_n + \underline{\Delta m}$$

$$236.05258 = 235.85973 + \Delta m$$

$$\Delta m = 0.19285$$

$$\Delta E = 0.19285 \times 931.49 = \boxed{179.64\ \text{MeV}}$$

Per atom reacting.

$1\text{MeV} = 1.6\times10^{-13}\text{J}$

$= 2.87\times10^{-11}\text{J}$

Scaling this to our perspective.

We know: 6.023×10^{23} atoms in 1mol

We also know: 1 mol of atoms has a mass of the mass number in grams.

ex. 1mol of ^{235}U has a mass of 235g

We have:

$$2.87\times10^{-11}\,\frac{J}{\cancel{atom}} \times 6.022\times10^{23}\,\frac{\cancel{atoms}}{\cancel{mol}} \times \frac{1\,\cancel{mol}}{235\,g} = 7.37\times10^{10}\,\frac{J}{g}$$