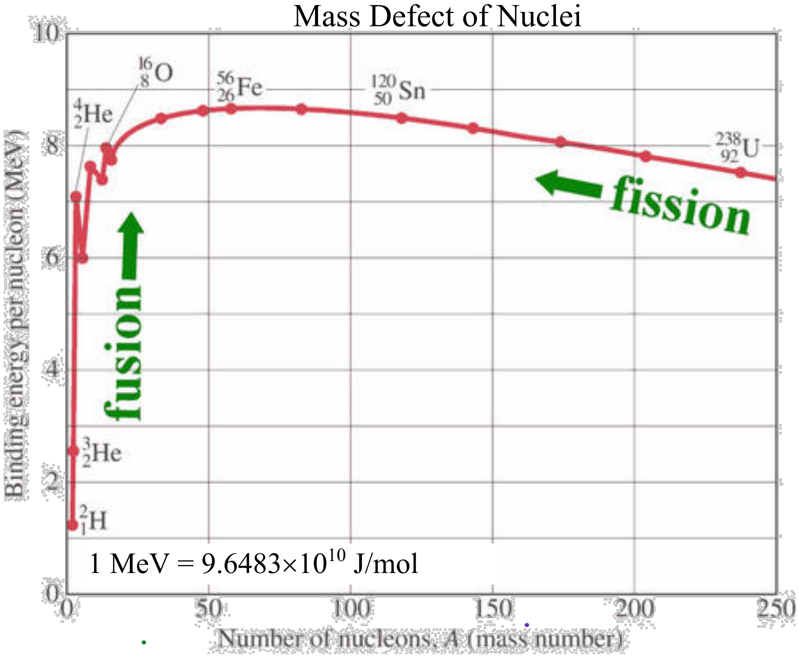
Notes 5-5: Chem H
Mass Defect and E = mc^2

Name__________________________________
Period_____ Date____________

Mass Defect

As nuclei form, the particles lose mass as it is converted to energy. This “mass defect” indicates the stability of the nucleus. Fe and Ni are the most stable nuclei, with the largest mass defects. As an atom undergoes fission or fusion toward Fe, their mass defect increases and it becomes more stable.

Mass Defect of Nuclei



Notes: **$\Delta E = \Delta mc^2$:**

Energy = (mass defect)(speed of light)^2
where the speed of light = 3.00×10^8 m/s

--Mass and energy can be thought of as two “forms” of the same thing. In a sense, mass can be turned into energy or energy can be turned into mass.

--For any reaction, mass must be lost, if energy is produced.

For chemical reactions, we usually assume that mass is conserved but really….

Nuclear reactions:

Sample problem: Suppose $^{23}_{11}Na$ is formed from its separate protons, neutrons and electrons. (Fusion!!!)

1) How much mass is lost when one atom of Na-23 is formed from its separate protons, neutrons and electrons? *(In other words, what is the mass defect?) The mass of one atom of Na-23 is 22.989767 amu. [Masses of individual particles, mass of amu in kg, and c are in Chart B of your reference pack.]*

a) STEP 1: Write out reaction and calculate the mass of the initial separate p, n and e.

$$11\ p \quad + \quad 12\ n \quad + \quad 11\ e \rightarrow {}^{23}_{11}Na$$

m_i = 11(1.007276 amu) + 12(1.008665 amu) + 11(0.0005486 amu)

m_i = 11.080036 amu + 12.10398 amu + 0.0060346 amu = ____________________

b) STEP 2: Calculate the final mass if needed. (In this case, it is told to us. m_f = mass of $^{23}_{11}Na$)

c) STEP 3: Calculate the mass defect (mass lost) for reaction. $\Delta m = m_i - m_f$

Δm = 23.1900506 amu – 22.989767 amu = ______________________

d) How much energy is released when one atom of Na-23 is formed from separate p, n and e? *(In other words, what is the binding energy of Na-23?)*
STEP 1: Convert your mass defect value from amu’s to kg.

$$\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \times \frac{1.6605\times10^{-27}\,\text{kg}}{1\ \text{amu}} = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_$$

STEP 2: Use E= mc^2 to solve for energy produced per atom.

$$E = (\underline{\qquad\qquad\qquad\qquad})(3.00\times10^{8}\,\text{m/s})^{2} = \underline{\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad}$$

e) Calculate how much energy is released when one mole of Na-23 is produced, in J/mol.

$$E = \frac{\qquad\qquad\qquad\qquad}{1\text{ atom}} \times \frac{6.022\times10^{23}\text{ atoms}}{1\text{ mol}} = \underline{\qquad\qquad\qquad\qquad\qquad\qquad\qquad}$$

f) Use the given conversion factor to calculate the binding energy (mass defect) of Na-23, in MeV/nucleon.

$$\left(\underline{\qquad\qquad\qquad\qquad} \times \frac{1\text{ MeV}}{9.6483\times10^{10}\text{ J/mol}}\right)\Big/\underline{\qquad}\text{ nucleons} = \underline{\qquad\qquad\qquad\qquad}$$

2) In the next problem, you will determine the mass defect and energy released for a nuclear reaction You will not calculate the mass defect since that applies only to the formation of an atom from its separate subatomic particles.

a) What is the mass change when U-238 (238.050788 amu) emits an α particle (4.001506 amu) and transmutes into Th-234 (234.043601 amu): ${}^{238}_{92}\text{U} \rightarrow {}^{4}_{2}\text{He} + {}^{234}_{90}\text{Th}$

m_i = 238.050788 amu

m_f = 4.001506 amu + 234.043601 amu = 238.045107 amu

$$\mathbf{\Delta m} = 238.050788\text{ amu} - 238.045107\text{ amu} =$$

b) Convert the mass change in amu to kg:

$$\underline{\qquad\qquad\qquad\qquad} \times \frac{1.6605\times10^{-27}\,\text{kg}}{1\text{ amu}} = \underline{\qquad\qquad\qquad\qquad\qquad}$$

c) Use E= mc^2 to solve for energy produced per atom.

$$E = (\underline{\qquad\qquad\qquad\qquad})(3.00\times10^{8}\,\text{m/s})^{2} = \underline{\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad}$$

d) Finally, use Avogadro's number to determine the energy released in J/mol:

$$E = \frac{\qquad\qquad\qquad\qquad}{1\text{ atom}} \times \frac{6.022\times10^{23}\text{ atoms}}{1\text{ mol}} = \underline{\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad}$$