Exercise 21.1a(H)

Mass Defect and Nuclear Binding Energy - Answers

Name: ____________________

Date:_______________ Per:________

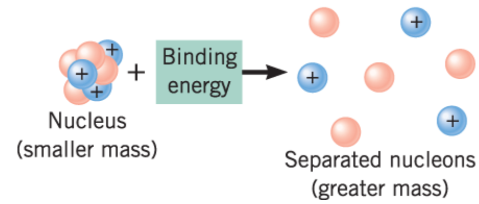
Nuclei are made up of protons and neutrons, but the mass of a nucleus is always less than the sum of the individual masses of the protons and neutrons which constitute it. The difference (mass defect) is a measure of the nuclear binding energy which holds the nucleus together. Nuclear binding energy is the energy required to disassemble a nucleus into free unbound neutrons and protons. Nuclear binding energy derives from the strong (nuclear) force and can be calculated from the mass-energy equivalence formula derived by Einstein:

$$\text{Nuclear binding energy(E)} = \text{mass defect}(\Delta m) \bullet \text{speed of light}(c)^2 \rightarrow E = mc^2$$

$$\text{mass defect}(\Delta m) = (\sum \text{masses of individual } p^+ \ \& \ n^o) - (\text{mass of the nucleus})$$

E = binding energy in joules, m = mass defect in kilograms, c = 3.00 x10^8 m/s

Particle	Relative Mass (u)	Conversion Factors
Electron	5.485779 x 10^{-4}	**1u = 1.6605 x 10^{-27} kg**
Proton	1.007276	**1eV = 1.60 x 10^{-19} joules**
Neutron	1.008665	



DIRECTIONS: Using the values above, answer the following in the space provided:

1. The mass of a neon–20 atom is 19.99244 u. Calculate its mass defect.

$10\ p^+ \quad + \quad 10\ n^0 \quad + \quad 10\ e^-$

$10(1.007276\ u) + 10(1.008665\ u) + 10(5.485779 \times 10^{-4}\ u) - 19.99244\ u = 0.1724557\ u \Rightarrow \boxed{0.17246\ u}$

2. The mass of a lithium–7 atom is 7.01600 u. Calculate it mass defect.

$3\ p^+ \quad + \quad 4\ n^0 \quad + \quad 3\ e^-$

$3(1.007276\ u) + 4(1.008665\ u) + 3(5.485779 \times 10^{-4}\ u) - 7.01600\ u = 0.0421337\ u \Rightarrow \boxed{0.04213\ u}$

3. Calculate the nuclear binding energy of one lithium–6 atom. The actual atomic mass of lithium–6 is 6.015 u.

$3\ p^+ \quad + \quad 3\ n^0 \quad + \quad 3\ e^-$ *mass defect*

$3(1.007276\ u) + 3(1.008665\ u) + 3(5.485779 \times 10^{-4}\ u) - 6.015\ u = 0.0344\ u$

$0.0344\ u \times \frac{1.6605 \times 10^{-27}\ kg}{1\ u} = 5.71 \times 10^{-29}\ kg$

$E = m \quad c^2$

$E = (5.71 \times 10^{-29}\ kg)(3.00 \times 10^8\ m/s)^2 = 5.139 \times 10^{-12}\ kg \bullet m^2/s^2 \Rightarrow \boxed{5.1 \times 10^{-12}\ J}$

4. Calculate the binding energy of one potassium–35 atom. The actual atomic mass of potassium–35 is 34.988011 u.

$19\ p^+ \quad + \quad 16\ n^0 \quad + \quad 19\ e^-$ *mass defect*

$19(1.007276\ u) + 16(1.008665\ u) + 19(5.485779 \times 10^{-4}\ u) - 34.988011\ u = 0.2992959\ u$

$0.2992959\ u \times \frac{1.6605 \times 10^{-27}\ kg}{1\ u} = 4.96980 \times 10^{-28}\ kg$

$E = m \quad c^2$

$E = (4.96980 \times 10^{-28}\ kg)(3.00 \times 10^8\ m/s)^2 = 4.47282 \times 10^{-11}\ kg \bullet m^2/s^2 \Rightarrow \boxed{4.47 \times 10^{-11}\ J}$

5. Calculate the mass defect and binding energy for the nuclide $^{10}_{5}B$ where the mass of $^{10}_{5}B$ atom = 10.0129 u.

$5\ p^+ \quad + \quad 5\ n^0 \quad + \quad 5\ e^-$ *mass defect*

$5(1.007276\ u) + 5(1.008665\ u) + 5(5.485779 \times 10^{-4}\ u) - 10.0129\ u = 0.06954\ u$

$0.06954\ u \times \frac{1.6605 \times 10^{-27}\ kg}{1\ u} = 1.154 \times 10^{-28}\ kg$

$E = m \quad c^2$

$E = (1.154 \times 10^{-28}\ kg)(3.00 \times 10^8\ m/s)^2 = 1.0386 \times 10^{-11}\ kg \bullet m^2/s^2 \Rightarrow \boxed{1.04 \times 10^{-11}\ J}$

Answers: 1) 0.17246 u 2) 0.04213 u 3) 5.1 x 10^{-12} J 4) 4.47 x 10^{-11} J 5) 1.04 x 10^{-11} J 6) 1.49 x 10^{-10} J, 934 MeV

Chemistry H

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6. Because binding energy is calculated using only one variable (*m*) and one constant (*c*), it is possible to calculate the binding energy for specific mass changes. Calculate the binding energy associated with a mass defect of 1.000*u* in both joules and MeV(megaelectronvolts).

Calculate the energy involved in a mass change of 1.000 u (i.e., 1.6605 x 10^{-27} kg):

E = m (of 1.000 *u*) c^2

E = (1.6605 x 10^{-27} kg) (3.00 x 10^{8} m/s)^2 = 1.49445 x 10^{-10} kg•m^2/s^2 ⇒ **1.49 x 10^{-10} J**

Convert the energy in joules to energy in electronvolts using the equivalence 1.60 x 10^{-19} J = 1 eV, then to megaelectronvolts.

1.494 x 10^{-10} J	1 eV	1 MeV
	1.60 x 10^{-19} J	1 x 10^{6} eV

= 933.7MeV ⇒ **934 MeV**

Answers: 1) 0.17246 u 2) 0.04213 u 3) 5.1 x 10^{-12} J 4) 4.47 x 10^{-11} J 5) 1.04 x 10^{-11} J 6) 1.49 x 10^{-10} J, 934 MeV