## 7.4 Questions

1. Determine the energy equivalent, in joules, of
   (a) an electron
   (b) a proton T/I C
2. A small sample of coal, when completely converted to energy, releases $4.5 \times 10^{14}$ J. Determine the original mass of the coal. Assume that the final mass is zero. T/I C
3. Calculate the energy released in the following nuclear reaction, given the masses indicated: T/I C
   $^{236}_{92}U \rightarrow ^{232}_{90}Th + ^{4}_{2}He$
   $m_{U\text{-}236} = 236.045\ 562$ u
   $m_{Th\text{-}232} = 232.038\ 051$ u
   $m_{He\text{-}4} = 4.003\ 603$ u
4. Calculate the energy released in the following reaction, given the masses indicated: T/I C
   $^{235}_{92}U + ^{1}_{0}n \rightarrow ^{90}_{38}Sr + ^{135}_{54}Xe + 11(^{1}_{0}n)$
   $m_{U\text{-}235} = 235.044$ u
   $m_{Sr\text{-}90} = 89.908$ u
   $m_{Xe\text{-}135} = 134.879$ u
5. The following shows the products of a uranium-238 decay series: K/U C
   $^{238}_{92}U \Rightarrow ^{234}_{90}Th \Rightarrow ^{234}_{91}Pa \Rightarrow ^{234}_{92}U \Rightarrow ^{230}_{90}Th \Rightarrow ^{226}_{88}Ra$
   (a) Write a nuclear reaction equation for each stage of this series. Assume that beta decay reactions are beta-negative.
   (b) Identify each reaction by type of decay. Explain your answers.
6. Refer to Question 5. This series of reactions is part of a longer one known as the uranium-lead series. K/U T/I
   (a) Research this series and identify the other reactions involved.
   (b) What is the final stable isotope?
7. Summarize the safety issues related to nuclear fission reactors. K/U C
8. Explain how CANDU reactors are designed to minimize danger due to electrical power loss. K/U C
9. The following illustrates the breeding chain used to produce plutonium-239 from uranium-238 in a breeder reactor. The process is initiated by bombarding U-238 with high-energy neutrons:
   $^{238}_{92}U + ^{1}_{0}n \rightarrow ^{239}_{92}U \rightarrow ^{239}_{93}Np \rightarrow ^{239}_{94}Pu$
   Classify the nuclear reactions occurring at each stage of this breeding cycle as alpha decay, beta decay, or electron capture. Then write a reaction equation for each stage. Assume that beta decay reactions are beta-negative. T/I C
10. Another breeding chain involves the transmutation of thorium-233 to uranium-233. This occurs in three stages: first a neutron is absorbed by a Th-233 nucleus, and then the daughter isotope undergoes beta-negative decay twice. Write the series of nuclear reaction equations for this breeding chain. Identify parent and daughter isotopes and their mass numbers and atomic numbers for each stage. T/I C

#1. $E = mc^2$   $m_e = 9.11 \times 10^{-31}$ kg   $m_p = 1.67 \times 10^{-27}$ kg
$E = (9.11 \times 10^{-31})(3 \times 10^8)^2$
$E = 8.2 \times 10^{-14}$ J electron   $E = 1.5 \times 10^{-10}$ J proton

2. $E = 4.5 \times 10^{14}$ J   $E = mc^2$
$4.5 \times 10^{14} = m(3 \times 10^8)^2$
$5 \times 10^{-3}$ kg $= m$
$0.005$ kg $= m$

3. $^{236}_{92}U \rightarrow ^{232}_{90}Th + ^{4}_{2}He$

Mass Difference $= 236.045562 - (232.038051 + 4.003603)$
$= 3.908 \times 10^{-3}$ u   $\left(\frac{1.66 \times 10^{-27} \text{ kg}}{1 \text{u}}\right)$
Note diff. units
$= 6.4873 \times 10^{-30}$ kg

$E = mc^2$
$E = (6.4873 \times 10^{-30}) \cdot (3 \times 10^8)^2$
$E = 5.839 \times 10^{-13}$ J
$E = 3.64$ MeV

5. $^{238}_{92}U \rightarrow ^{234}_{90}Th + ^{4}_{2}He$ (alpha)
$^{234}_{90}Th \rightarrow ^{234}_{91}Pa + ^{0}_{-1}e$ (β Negative)
$^{234}_{91}Pa \rightarrow ^{234}_{92}U + ^{0}_{-1}e$ (β Negative)
$^{234}_{92}U \rightarrow ^{230}_{90}Th + ^{4}_{2}He$ (alpha)
$^{230}_{90}Th \rightarrow ^{226}_{88}Ra + ^{4}_{2}He$ (alpha)

## 7.5 Questions

1. Compare and contrast nuclear fission and nuclear fusion. How are these reactions alike? How are they different? K/U C
2. (a) Explain why nuclear fusion is more difficult to achieve than nuclear fission.
   (b) Why is nuclear fusion more desirable than nuclear fission for power generation? K/U C
3. Use the following values to answer (a) and (b): T/I C

   $m_{H\text{-}1} = 1.007\ 825$ u

   $m_{C\text{-}12} = 12.000\ 00$ u

   $m_{C\text{-}13} = 13.003\ 35$ u

   $m_{N\text{-}14} = 14.003\ 07$ u

   (a) Determine the amount of energy released in the third stage of the carbon-nitrogen-oxygen cycle:

   $$^{13}_{6}C + ^{1}_{1}H \Rightarrow ^{14}_{7}N + \text{energy}$$

   (b) In the first stage of the carbon-nitrogen-oxygen cycle, 1.95 MeV is produced per reaction:

   $$^{12}_{6}C + ^{1}_{1}H \Rightarrow ^{13}_{7}N + \text{energy}$$

   Use this information to determine the mass of nitrogen-13. T/I
4. Refer to Tutorial 1 on page 343.
   (a) Determine the energy released per nucleon for the fission and fusion reactions in Sample Problems 1 and 2.
   (b) What is illustrated by comparing these energy values? K/U T/I C
5. Deuterium can be extracted from normal water, and tritium is a waste product of CANDU reactors. What does this suggest about the fuel availability for nuclear fusion reactors? A
6. Consider the carbon-nitrogen-oxygen cycle:

   $$^{12}_{6}C \Rightarrow ^{13}_{7}N \Rightarrow ^{13}_{6}C \Rightarrow ^{14}_{7}N \Rightarrow ^{15}_{8}O \Rightarrow ^{15}_{7}N \Rightarrow ^{12}_{6}C + ^{4}_{2}He$$

   The first two reaction equations of this cycle are

   $$^{12}_{6}C + ^{1}_{1}H \Rightarrow ^{13}_{7}N + \text{energy}$$

   $$^{13}_{7}N \Rightarrow ^{13}_{6}C + ^{0}_{+1}e + \text{energy}$$

   (a) Which of these is a fusion reaction? Explain.
   (b) Which of these is a beta decay reaction? What type of beta decay is it? Explain how you know.
   (c) Write the remaining reaction equations for this cycle and classify each by type of nuclear reaction. Assume that the beta decay reactions are of the same type as the one given above. K/U T/I C
7. Perform some research on nuclear fusion techniques. What are some alternative methods for controlling nuclear fusion that have not been discussed in this section? Write a sentence or two to describe how each of these works. Include diagrams to support your explanations. T/I C
8. Conduct research on the ITER project. What advances have been made since the publication of this text? T/I

GO TO NELSON SCIENCE

1. Fusion - combines atoms together to release energy and make new atoms/products.

   Fission - breaks apart atoms (usually through collisions) to release energy & make new atoms/products.

3. $^{13}_{6}C + ^{1}_{1}H \rightarrow ^{14}_{7}N + \text{energy}$

   Mass Defect $= 13.00335u + 1.007825 - 14.00307$

   M.D. $= 8.105 \times 10^{-3}$ u $= 1.2984 \times 10^{-29}$ kg

   $E = mc^2$

   $E = (1.2984\times10^{-29})(3\times10^{8})^2 = 1.1686\times10^{-12}$ J

   OR

   $E = (8.105\times10^{-3}u)\left(\frac{930\text{ MeV}}{u}\right) = 7.538$ MeV

   (same (difference is rounding))

6. (a) $^{12}_{6}C + ^{1}_{1}H \rightarrow ^{13}_{7}N + \text{energy}$ → Fusion, combining together to make larger elements.

   (b) $^{13}_{7}N \rightarrow ^{13}_{6}C + ^{0}_{+1}e$ → Beta Positive Decay (proton balance)

   (c) $^{13}_{6}C + ^{1}_{1}H \rightarrow ^{14}_{7}N$ Fusion

   $^{14}_{7}N + ^{1}_{1}H \rightarrow ^{15}_{8}O$ Fusion

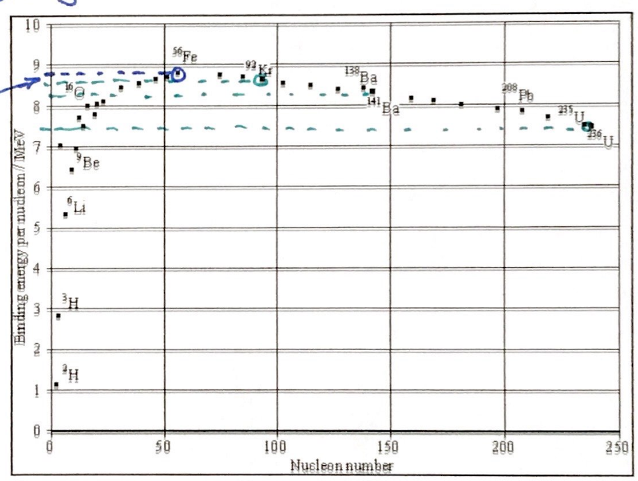
   $^{15}_{8}O \rightarrow ^{15}_{7}N + ^{0}_{+1}e$ Beta positive Decay

   $^{15}_{7}N + ^{1}_{1}H \rightarrow ^{12}_{6}C + ^{4}_{2}He$ Fusion & alpha Decay

**Do ALL work on a separate page please. There is not enough room to answer on this page.**

1. Explain what isotopes are. How are the isotopes of a particular element similar? How are they different?
   Isotopes are variations of an element; they have the same # of protons but different # neutrons
2. An element has a mass number of 38 and is the 15th element on the periodic table. How many neutrons does it have?
   AM - AN = 38 − 15
   = 23 neutrons
3. Explain what an artificial transmutation is and give two examples of artificial transmutations.
   A.T. → isotope creation by humans. ie N + α → O + H     $\alpha = {}^4_2He$
   Al + α → P + n
4. Define the concept of *unified atomic mass*.
   Mass measurement (atomic level), $\frac{1}{12}$ neutral carbon-12 atom.
5. Define the concept of *mass defect*.
   Difference of mass between products & reactants (parent / daughter)
6. Define the concept of *binding energy*.
   Minimum energy required to remove a particle from a system (linked to mass defect).
7. Define the concept of *binding energy per nucleon*. (proton/neutron) (Nucleus)
   Energy required to pull one Nucleon free of the Nucleus. ( $\frac{\text{Binding Energy}}{\text{\# of Nucleons}}$ )
8. A nitrogen atom has a mass of precisely 14.00307 u. How many kilograms is this?
   $14.00307u \left(\frac{1.66\times10^{-27}kg}{1u}\right) = 2.3245\times10^{-26}$ kg
9. How many joules would be released by the complete conversion of 1.250 kg into pure energy?
   $E = mc^2$   $E = (1.250)(3\times10^8)^2$
   $E = 1.125\times10^{17}$ J

*The graph shows the binding energy per nucleon vs. number of nucleons. The following questions refer to this graph.*




10. What is the binding energy per nucleon of $^{56}$Fe?
    ≈ 8.8 MeV

11. What, then, is the total binding energy of $^{56}$Fe?
    8.8 × 56 = 492.8 MeV

12. What amount of work would be required to completely disassemble $^{56}$Fe into its constituent nucleons?
    492.8 MeV
13. Find the sum of the binding energies of $^{92}$Kr and $^{141}$Ba.
    $^{92}$Kr = 92 × 8.6 = 791.2 MeV
    $^{141}$Ba = 141 × 8.4 = 1184.4 MeV
    Total 1975.6 MeV
14. Find the binding energy of $^{236}$U.
    $^{236}$U = 7.4 × 236
    = 1746.4 MeV
15. From the previous two problems, find the gain in binding energy that occurs when uranium-236 splits into barium-141 and krypton-92.
    Binding Energy = 1975.6 − 1746.4
    = 229.2 MeV
16. Explain which type of reaction this is (fission or fusion) and why it occurs naturally.
    $^{236}U \rightarrow {}^{141}Ba + {}^{92}K + 3n$   Fission, unstable, moving to stable.

*The following questions refer to the reaction shown below, in which a high-energy alpha particle collides with a nitrogen nucleus. Use the given table as needed.*

| | particle | rest mass / *u* |
|---|---|---|
| R | He | 4.00260 |
| R | N | 14.00307 |
| P | O | 16.99913 |
| P | p | 1.00783 |

17. Complete the nuclear reaction shown here:
    $${}^{14}_{7}N + {}^{4}_{2}He \rightarrow {}^{17}_{8}O + {}^{1}_{1}p$$
18. Find the mass in *u* of the reactants. → 18.00567 u
19. Find the mass in *u* of the products. → 18.00696 u
20. Explain why this reaction is an artificial transmutation that is not likely to occur naturally.
    Mass Defect = 18.00696 − 18.00567
    = 0.00129 u (increase in mass) of products
    Energy would have to be put INTO the system for the reaction to take place