COMMENTS ON ASSIGNMENT 3

1. In nuclear astrophysics and almost everywhere in astronomy, one needs to move quickly between temperature and electron volts. Adopting E=kT determine the temperature equivalent for for 1 eV.

   The hard work of conversion is done by Iliadis in his Table E.1 where he gives

   $k=8.6173324(78) \times 10^{-5}$ eV/K^{-1} and

   From this 1 eV=11605 K to adequate accuracy.

   Very often, it suffices to recall that

   1 eV=10000K or MeV=10^{10} K

2. In many circumstances, one encounters expressions such as Ø = exp(E/kT). Often, one knows E in eV and then it is convenient to recognize that Ø = $10^{-\Theta X}$ where $\mathbf{X} = (\equiv \mathbf{E})$ is in eV and Θ =5040/T

   Using the table E. 1 from Iliadis estimate a more precise value of the constant 5040.

   $e^{E/kt} = 10^{-\Theta X} = 10^{aX/T}$

   Recall that $\log_{10} x = \ln x/\ln 10$
   $= \ln x/2.302585$

   Then, $\frac{\boldsymbol{E}}{\boldsymbol{k}} = 2.302585\ \mathbf{X}$

   With $k=8.6173324 \times 10^{-5}$ eV/K,
   $a=10^5/(8.6173324 \times 2.3025851)$
   $= 5039.78$ K/eV

3. Determine the number of protons, $\boldsymbol{Z}$, and the number of neutrons, $\boldsymbol{N}$, for the nuclides ^{18}F, ^{56}Ni, ^{82}Rb, ^{120} In, ^{150}Gd, and ^{235}U.

   Straight forward! Chemical symbol provides $\boldsymbol{Z}$ and $\boldsymbol{N}$ is obtained from the mass number A given as the preceding script. Thus, ^{18}F has $\boldsymbol{Z}$ =9 and $\boldsymbol{N}$=18-9=9.

4. How much energy is released in the following reactions: (i) ^{3}He(d,p)^{4}He;(ii)^{17}O(p, γ)^{18}F; (iii) ^{12}C(α,γ)^{16}O; and (iv) ^{13}C(α,n)^{16}O? Assume that the reactions involve nuclei only in their ground states. Use the results presented in Table 1.1.

   Recall Iliadis Sec. 1.5.3 and his Example 1.3.

   ^{3}He(d,p)^{4}He $\rightarrow$
   $Q=(ME)^3_{He} + (ME)_d - (ME)_p - (ME)^4_{He}$
   $=14931.2155 + 13135.7217 - 7288.9706 - 2424.9156 =$
   18353.05 [keV] $= 18.353$ [MeV]

5. With the aid of Figure 1.11, predict the spins and parities of ^{19}O, ^{31}P, and ^{37}Cl for both the ground state and the first excited state. Compare your answer with the observed values. These can be found in Endt (1990) and Tilley *et al.* (1995)

   ^{19}O has 8 protons and 11 neutrons and is NOT a stable nuclide but is one that has been manufactured and studied. I cheated and looked up the energy level diagram in Tilley *et al.* (1995) — see their Table 19.2 and Figure 6. The ground state has $J^\pi = \frac{5^+}{2}$ and the first excited state at just 0.0960 MeV above the ground state has $J^\pi = \frac{3^+}{2}$.

6. Suppose that an excited state with spin and parity of 2^+ in a nucleus of mass A = 20 decays via emission of a γ-ray with a branching ratio of 100% to a lower lying level with spin and parity of 0^+. Assume that the γ-ray energy amounts to $E_\gamma = E_i - E_f = 6$ MeV. Estimate the maximum expected γ-ray transition probability $\Gamma = \lambda\hbar$.

   First step is to determine the type of the transition. $2^+ \rightarrow 0^+$ is an electric quadrupole or E2 transition. Then, equation 4-24 on p. 50 applies:

   λ_W (E2) $\hbar = 4.9 \times 10^{-8} A^{4/3} E^5$ and $\Gamma = \lambda\hbar = (4.9 \times 10^{-8})\ 20^{4/3}\ 6^5 = 0.021$eV.

7. Consider a nucleus in a plasma at thermal equilibrium. Calculate the population probabilities of the ground state ($E_0 = 0$) and of the first three excited states (E_1 = 0.1 MeV, E_2 = 0.5 MeV, E_3 = 1.0 MeV). Perform the computations for two temperatures, $T = 1.0 \times 10^9$ K and 3.0×10^9 K, and assume for simplicity that all states have the same spin value.

   One interpretation of "population probabilities" is simply n_1/n_0, n_2/n_0 and n_3/n_0.

   Alternatively, we might suppose that what is needed is n_ι / n_{total} where $n_{total} = \Sigma \frac{ni}{i}$ is a sum all states, a sum generally called the partition function.