Practice Problems: Nuclear Chemistry

1. Write the equation for the nuclear reaction described in each of the following processes:

   a. Fluorine-18 ($^{18}\text{F}$) undergoes positron emission (one of the radionuclides used in PET scans)

   b. Technetium-99m ($^{99m}\text{Tc}$) undergoes gamma decay to form $^{99}\text{Tc}$ (a diagnostic radioactive tracer used to locate tumors, the “m” indicates a metastable excited nuclear state)

   c. Chromium-51 ($^{51}\text{Cr}$) undergoes electron capture (a diagnostic radioactive tracer used to study blood)

2. Would you expect the three radionuclides described in Problem 1 to have short half-lives (minutes to days) or long half-lives (years)? Explain why.

3. The decay series of Americium-241 (used in smoke detectors) eventually forms bismuth-209. Determine how many alpha decays and how many beta decays occur in the series, and write the overall nuclear reaction. Explain your reasoning.
4. Rocks can be dated using the beta decay of $^{40}$K into $^{40}$Ar. Assuming that there was no gaseous argon in the molten rock when it formed, and that all of the argon produced since solidification has remained trapped in the rock until it was crushed for analysis, use the following information to calculate the age of the rock in years BP (before present, 1950): Year analyzed: 2011, $^{40}$Ar/$^{40}$K ratio in the rock = 1.15, $t_{\frac{1}{2}}$ of $^{40}$K = 1.28 x 10$^9$ years.

5. The energy yield of nuclear weapons is measured in Mt (megatonnes of TNT). If the explosion of 1 tonne of TNT yields 4.2 GJ (gigajoules) of energy, what mass (in kg) of matter was converted to energy in the 57 Mt blast of the largest weapon ever tested (Tzar Bomba, USSR, 1961)?

$c = 2.998 \times 10^8$ m/s
6. What is the binding energy of $^{12}$C (in kJ/mol and MeV/nucleon)?

7. How much energy (in kJ/mol) is released in the following fusion reaction occurring in the plasma phase? Hint: There are a total of 3 $e^-$ missing (compared to the neutral atoms given in the table) on both sides of the reaction, therefore their masses do not affect the change in mass.

$$^2_1\text{H} + ^3_2\text{He} \rightarrow ^4_2\text{He} + ^1_1\text{H}$$