1. Indicate whether the following statements are true (T) or false (F). [30 points]

( ) The isotopic abundance of deuterium is greater than that of $^3$He.

( ) A sample containing $10^{22}$ atoms of $^{56}$Fe has a mass greater than 1 gram.

( ) The energy of a photon increases as its wavelength decreases.

( ) An electromagnetic wave has no rest mass but does have momentum.

( ) A nucleus in an excited state has a greater mass than the same nucleus in its ground state.

( ) In Einstein’s famous equation $E = mc^2$, $m$ is the rest mass.

( ) The uncertainty principle refers to a student’s nervousness before an exam.

( ) Elements heavier than iron ($Z = 26$) are created in supernova explosions by absorption of many neutrons in lighter nuclei followed by a series of positron decays.

( ) During the big bang and the rapid expansion of the early universe, only elements lighter than boron were formed.

( ) In radioactive decay, the Q-value is never negative.

( ) The smaller the half-life of a radionuclide, the larger is its decay constant.

( ) If activity of a radionuclide source drops to one-eighth of its initial activity in 8 hours, the radioisotope has a half-life of one hour.

( ) A 1 mCi source has an activity greater than 40 MBq.

( ) Some fissile nuclei can be converted into fertile nuclei by the absorption of a neutron.

( ) The Q-value for elastic scattering from a nucleus is always greater than that for inelastic scattering from the same nucleus.
2. Consider the reaction $^{24}\text{Mg}(\alpha,\text{p})^{27}\text{Al}$.

(a) What is the Q-value for this reaction?

(b) What is the kinematic threshold energy for this reaction?

(c) What is the Coulombic threshold energy for this reaction?

(d) What is the minimum kinetic energy of the products?

[30 points]
3. A sample of a stable nuclide is placed in a reactor where a radionuclide with a half-life of 2 hours is produced in the sample at a constant rate of $2 \times 10^{10}$ radionuclides per second.

(a) What is the maximum activity (in Bq) that can be produced in the sample?

(b) What is its activity of the sample 4 hours after removal from the reactor if the maximum activity is achieved at the time of removal?

[20 points]
4. A particular fission reaction can be represented as follows

\[ { }_0^1 \text{n} + { }_{92}^{235}\text{U} \rightarrow { }_{38}^{90}\text{Sr} + \frac{A}{2}\text{X} + 3{ }_0^1\text{n} + \gamma_p \]

(a) What element is X?
(b) Which isotope of element X is produced
(c) What is the meaning of \( \gamma_p \)

[20 points]