Print your name ____

Problems [3 points each for In-class problem. Total 97 points]

Directions: Show your work step by step to receive full credit. Box your final answer and record its appropriate unit.

Some Commonly Used Constants and Conversion Factors

(see Appendix A for a more complete list)

Speed of light	$c = 2.998 \times 10^8$ m/s
Electronic charge	$e = 1.602 \times 10^{-19}$ C
Boltzmann constant	$k = 1.381 \times 10^{-23}$ J/K $= 8.617 \times 10^{-5}$ eV/K
Planck's constant	$h = 6.626 \times 10^{-34}$ J·s $= 4.136 \times 10^{-15}$ eV·s
Avogadro's constant	$N_A = 6.022 \times 10^{23}$ mole $^{-1}$
Electron mass	$m_e = 5.49 \times 10^{-4}$ u $= 0.511$ MeV/c^2
Proton mass	$m_p = 1.007276$ u $= 938.3$ MeV/c^2
Neutron mass	$m_n = 1.008665$ u $= 939.6$ MeV/c^2
Bohr radius	$a_0 = 0.0529$ nm
Hydrogen ionization energy	13.6 eV
Thermal energy	$kT = 0.02525$ eV $\cong \frac{1}{40}$ eV ($T = 293$ K)
$hc = 1240$ eV·nm (MeV·fm)	$\hbar c = 197$ eV·nm (MeV·fm)
$\dfrac{e^2}{4\pi\varepsilon_0} = 1.440$ eV·nm (MeV·fm)	1 u $= 931.5$ MeV/c^2 1 eV $= 1.602 \times 10^{-19}$ J

In Class Problem 27-36, total 30 points.

3-1) (3 points)

What is the nuclear radius of (a) ^{197}Au; (b) ^{4}He; (c) ^{20}Ne? **Please estimate it use the scaling law of nuclear radius.**

3-2) (4 points)

Find the total binding energy, and the binding energy per nucleon, for (a) ^{208}Pb; (b) ^{133}Cs; (c) ^{90}Zr; (d) ^{59}Co.

3-3) (3 points)

The nuclear attractive force must turn into a repulsion at very small distances to keep the nucleons from crowding too close together. What is the mass of an exchanged particle that will contribute to the repulsion at separations of 0.25 fm?

提示：利用海森堡不确定性关系，exchange particle 一般都是光速的规范玻色子。

3-4) (6 points)

Prove the release energy for the following nuclear decay. Assume the neutrino energy is negligible small and m represent the atomic mass.

For $^{A}_{Z}X_N \longrightarrow {}^{A}_{Z+1}X'_{N-1} + e^- + \bar{\nu}$

The Q value for this decay is

$$Q = [m(^AX) - m(^AX')]c^2$$

For $^{A}_{Z}X_N \longrightarrow {}^{A}_{Z-1}X'_{N+1} + e^+ + \nu$

$$Q = [m(^AX) - m(^AX') - 2m_e]c^2$$

For $^{A}_{Z}X_N + e^- \longrightarrow {}^{A}_{Z-1}X'_{N+1} + \nu$

$$Q = [m(^AX) - m(^AX')]c^2$$

3-5) (3 points)

^{40}K is an unusual isotope, in that it decays by negative beta emission, positive beta emission, and electron capture. Find the Q values for these decays.

3-6) (3 points)

^{12}N beta decays to an excited state of ^{12}C, which subsequently decays to the ground state with the emission of a 4.43-MeV gamma ray. What is the maximum kinetic energy of the emitted beta particle?

3-7) (4 points)

Compute the Q value for the $^{238}U \rightarrow {}^{206}Pb$ decay chain, and find the rate of energy production per gram of uranium.

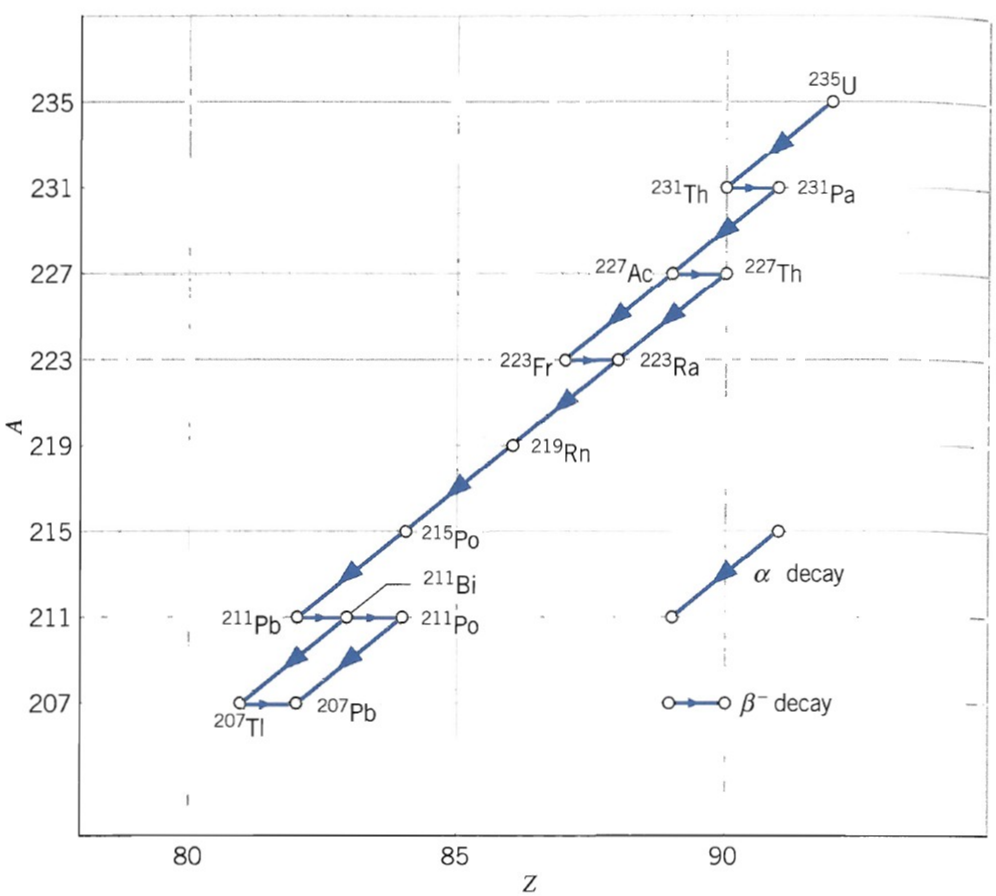

FIGURE 12.17 The ^{235}U decay chain.

3-8) (4 points)

Fill in the missing particle in these reactions:

(a) $^{4}He + {}^{14}N \rightarrow {}^{17}O +$ (c) $^{27}Al + {}^{4}He \rightarrow n +$

(b) $^{9}Be + {}^{4}He \rightarrow {}^{12}C +$ (d) $^{12}C + \quad \rightarrow {}^{13}N + n$

3-9) (4 points)

Calculate the threshold kinetic energy for the reaction

$$p + {}^{3}_{1}H_{2} \longrightarrow {}^{2}_{1}H_{1} + {}^{2}_{1}H_{1}$$

(*a*) If protons are incident on ^{3}H at rest. (*b*) If ^{3}H (tritons) are incident on protons at rest.

3-10) (3 points)

In the reaction $^{2}H + {}^{3}He \rightarrow p + {}^{4}He$ deuterons of energy 5.000 MeV are incident on ^{3}He at rest. Both the proton and the alpha particle are observed to travel along the same direction as the incident deuteron. Find the kinetic energies of the proton and the alpha particle.

3-11) (3 points)

Find the Q value (and therefore the energy released) in the fission reaction $^{235}U + n \rightarrow {}^{93}Rb + {}^{141}Cs + 2n$. Use $m({}^{93}Rb) = 92.92195$ u and $m({}^{141}Cs) = 140.92005$ u.

3-12) (3 points)

How much energy is required (in the form of gamma-ray photons) to break up ^{7}Li into $^{3}H + {}^{4}He$? This reaction is known as *photodisintegration*.

3-13) (4 points)

Suppose we have 100.0 cm^3 of water, which is 0.015 percent D_2O. (a) Compute the energy that could be obtained if all the deuterium were consumed in the $^{2}H + {}^{2}H \rightarrow {}^{3}H + p$ reaction. (b) As an alternative, compute the energy released if two-thirds of the deuterium were fused to form ^{3}H, which is then combined with the remaining one-third in the D-T reaction.

3-14) (5 points)

Each of the following reactions violates one (or more) of the conservation laws. Name the conservation law violated in each case:

(a) $\nu_e + p \rightarrow n + e^+$

(b) $p + p \rightarrow p + n + K^+$

(c) $p + p \rightarrow p + p + \Lambda^0 + K^0$

(d) $\pi^- + n \rightarrow K^- + \Lambda^0$

(e) $K^- + p \rightarrow n + \Lambda^0$

3-15) (3 points)

A Σ^- with a kinetic energy of 0.250 GeV decays into $\pi^- + n$. The π^- moves at 90° to the original direction of travel of the Σ^-. Find the kinetic energies of π^- and n and the direction of travel of n.

3-16) (3 points)

It is desired to form a beam of Λ^0 particles to use for the study of reactions with protons. The Λ^0 are produced by reactions at one target and must be transported to another target 2.0 m away so that at least half of the original Λ^0 remain in the beam. Find the speed and the kinetic energy of the Λ^0 for this to occur.

3-17) (6 points)

Find a decay mode, other than that listed in Table 14.6, for (a) Ω^-; (b) Λ^0; (c) Σ^+, that satisfies the applicable conservation laws.

3-18) (3 points)

Find the maximum energy of the positrons and of the π mesons produced in the decay $K^+ \rightarrow \pi^0 + e^+ + \nu_e$