

Name _____

Rec. Instr. _____

Rec. Time _____

For full credit, make your work clear. Show formulas used, essential steps, and results with correct units and significant figures. Points shown in parenthesis. For TF and MC, choose the *best* answer.

1. (2) Nuclei with the same atomic numbers but different mass numbers are known as
a. siblings b. isotopes. c. isomers. d. nucleons. e. muons.

2. (2) For a nuclide with atomic number Z and neutron number N , the mass number A is
a. Z/N b. N/Z c. $Z + N$. d. $Z - N$. e. $Z \times N$.

3. (2) For a stable nuclide of mass M , the sum of the masses of its constituent protons and neutrons when completely separated is
a. less than M . b. equal to M . c. greater than M .

4. (2) For heavy stable nuclei with N neutrons and Z protons, which relation holds?
a. $Z > N$. b. $Z = N$. c. $Z < N$.

5. (4) How many neutrons and how many protons make up one ${}_{93}^{237}\text{Np}$ (neptunium) nucleus?

- 6. (2) Generally speaking, which type of radiation from unstable nuclei is the most penetrating?
a. α radiation. b. β radiation. c. γ radiation.

- 7. (2) For which type of decay process is the daughter nucleus the same as the parent nucleus?
a. α emission. b. β^- emission. c. β^+ emission. d. γ emission.

- 8. (2) For which type of decay process does the daughter nucleus have one more proton than the parent nucleus?
a. α emission. b. β^- emission. c. β^+ emission. d. γ emission.

- 9. (2) For which type of decay process does the daughter nucleus have two less protons than the parent nucleus?
a. α emission. b. β^- emission. c. β^+ emission. d. γ emission.

- 10. (2) Which type of particle detector gives a sharp clicking sound when radiation enters it?
a. Geiger counter. b. scintillation counter. c. cloud chamber. d. bubble chamber.

- 11. (2) Which type of particle detector uses a saturated vapor to show particle tracks?
a. Geiger counter. b. scintillation counter. c. cloud chamber. d. bubble chamber.

- 12. (10) The atomic mass of ${}_{93}^{237}\text{Np}$ (neptunium) is 237.048167 u. Determine the binding energy per nucleon for the nucleus, in MeV/nucleon. (See equation sheet for neutron and other masses.)

13. (2) **T F** Carbon-14 dating is used to find the ages of objects millions of years old.
14. (2) **T F** After one half-life, half the mass of a radioactive sample has decayed.
15. (2) **T F** After two half-lives, the entire mass of a radioactive sample has decayed.
16. (2) **T F** Of all the stable nuclei, ${}^{56}_{26}\text{Fe}$ has the greatest binding energy per nucleon.
17. (2) **T F** In spontaneous nuclear decays, the parent's mass is always greater than that of the daughter.
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18. (3) Carbon-14 comes from a transmutation reaction in Earth's atmosphere, $n+X \rightarrow {}^{14}_6\text{C} + p$. Determine what X is, including its symbol from the periodic table and the atomic number and mass number.

19. (3) If the nuclide ${}^{211}_{83}\text{Bi}$ (bismuth-211) decays spontaneously by α emission, what is the daughter nuclide (give the symbol with atomic number and mass number)?

20. (3) If the nuclide ${}^{211}_{83}\text{Bi}$ decays spontaneously by β^- emission, what is the daughter nuclide (give the symbol with atomic number and mass number)?

21. (18) ${}^{211}_{83}\text{Bi}$ undergoes radioactive decay (by α , β^- and γ emissions) with a half-life of 2.14 minutes. At some starting time, suppose you have a 1.00 microgram sample.

a) (6) How many ${}^{211}_{83}\text{Bi}$ nuclei are initially present in the sample?

b) (6) What is the initial (radio-) activity of the sample, in decays per second?

c) (6) How many nuclei of ${}^{211}_{83}\text{Bi}$ remain after 10.0 minutes have passed?

22. (12) Radium (${}^{226}_{88}\text{Ra}$, mass = 226.025403 u) decays into radon (mass = 222.017570 u) by the α -emission reaction, ${}^{226}_{88}\text{Ra} \rightarrow {}^{222}_{86}\text{Rn} + {}^4_2\text{He}$. Find the disintegration energy Q of this reaction, in MeV.

23. (12) The common form of oxygen is ${}^{16}_8\text{O}$. Suppose a proton is removed from the nucleus.

a) (3) After the proton is removed, what is the new nucleus (give symbol with A and Z)?

b) (9) How much energy is required to remove the proton? You may need masses from the equation sheet. Give the answer in MeV.

24. (16) Find the missing symbol (with A and Z if appropriate) for each reaction:

a) $X \rightarrow {}^{30}_{14}\text{Si} + \beta^+$. $X =$

b) ${}^{24}_{12}\text{Mg} \rightarrow X + \gamma$. $X =$

c) $X \rightarrow {}^{214}_{83}\text{Bi} + \alpha$. $X =$

d) $n + {}^{235}_{92}\text{U} \rightarrow {}^{133}_{55}\text{Cs} + {}^{85}_{37}\text{Rb} + X$. $X =$

25. (2) Nuclear reactions where small nuclei combine to form larger nuclei are called

a. fission. b. fusion. c. transmutation. d. sequestration.

26. (2) Nuclear reactions where larger nuclei split into smaller ones are called

a. fission. b. fusion. c. transmutation. d. sequestration.

27. (2) Which set of nuclear reactions is thought to be responsible for the Sun's energy output?

a. uranium cycle. b. CNO cycle. c. proton-proton cycle. d. electron-positron cycle.

28. (10) A nuclear scientist bombards stationary ${}^7_3\text{Li}$ nuclei (atomic mass = 7.016004 u) with protons in the reaction, $p + {}^7_3\text{Li} \rightarrow {}^4_2\text{He} + \alpha$. What minimum kinetic energy in MeV must the protons have to make this reaction take place?

29. (18) One type of fusion reaction is the DT reaction, ${}^2_1\text{H} + {}^3_1\text{H} \rightarrow {}^4_2\text{He} + n$, which releases $Q = 17.59$ MeV of energy. A reactor uses this reaction to produce an energy output of 6000 kWh (equivalent of 12 months \times 500 kWh/month for a home's annual electrical needs).

a) (6) How many of the indicated reactions must take place to produce 6000 kWh?

b) (6) How much total mass of reactants (combined deuterium plus tritium) is needed?

c) (6) How much mass was converted to energy, according to Einstein's most famous equation?

Prefixes

a=10⁻¹⁸, f=10⁻¹⁵, p=10⁻¹², n=10⁻⁹, μ = 10⁻⁶, m=10⁻³, c=10⁻², k=10³, M=10⁶, G=10⁹, T=10¹², P=10¹⁵

Physical Constants

$$k = 1/4\pi\epsilon_0 = 8.988 \text{ GN}\cdot\text{m}^2/\text{C}^2 \text{ (Coulomb's Law)}$$

$$e = 1.602 \times 10^{-19} \text{ C (proton charge)}$$

$$c = 3.00 \times 10^8 \text{ m/s (speed of light)}$$

$$m_e = 9.1094 \times 10^{-31} \text{ kg = (electron mass)}$$

$$m_n = 1.67493 \times 10^{-27} \text{ kg = (neutron mass)}$$

$$h = 6.6262 \times 10^{-34} \text{ J}\cdot\text{s (Planck's constant)}$$

$$\epsilon_0 = 1/4\pi k = 8.854 \text{ pF/m (permittivity of space)}$$

$$\mu_0 = 4\pi \times 10^{-7} \text{ T}\cdot\text{m/A (permeability of space)}$$

$$c = 2.99792458 \times 10^8 \text{ m/s (exact value in vacuum)}$$

$$m_p = 1.67262 \times 10^{-27} \text{ kg = (proton mass)}$$

$$hc = 1240 \text{ eV}\cdot\text{nm (photon energy = } hc/\lambda)$$

$$\hbar = 1.05459 \times 10^{-34} \text{ J}\cdot\text{s (Planck's constant}/2\pi)$$

Units

$$N_A = 6.02 \times 10^{23}/\text{mole (Avogadro's \#)}$$

$$1.0 \text{ eV} = 1.602 \times 10^{-19} \text{ J (electron-volt)}$$

$$1 \text{ F} = 1 \text{ farad} = 1 \text{ C/V} = 1 \text{ C}^2/\text{J}$$

$$1 \text{ A} = 1 \text{ ampere} = 1 \text{ C/s} = 1 \text{ coulomb/second}$$

$$1 \text{ T} = 1 \text{ tesla} = 1 \text{ N/A}\cdot\text{m} = 1 \text{ newton/ampere-meter}$$

$$1 \text{ Bq} = 1 \text{ becquerel} = 1 \text{ decay/s}$$

$$1 \text{ u} = 1 \text{ g}/N_A = 1.6605 \times 10^{-27} \text{ kg} = 931.5 \text{ MeV}/c^2$$

$$1 \text{ V} = 1 \text{ volt} = 1 \text{ J/C} = 1 \text{ joule/coulomb}$$

$$1 \text{ H} = 1 \text{ henry} = 1 \text{ V}\cdot\text{s/A} = 1 \text{ J/A}^2$$

$$1 \Omega = 1 \text{ ohm} = 1 \text{ V/A} = 1 \text{ J}\cdot\text{s/C}^2$$

$$1 \text{ G} = 1 \text{ gauss} = 10^{-4} \text{ T} = 10^{-4} \text{ tesla}$$

$$1 \text{ Ci} = 1 \text{ curie} = 3.70 \times 10^{10} \text{ decays/s} = 37.0 \text{ GBq}$$

Some Masses (for neutral atoms)

$$\text{electron} = {}^0_1\text{e} = 0.00054858 \text{ u} = 0.51100 \text{ MeV}/c^2$$

$$\text{neutron} = {}^1_0\text{n} = \text{n} = 1.008665 \text{ u} = 939.57 \text{ MeV}/c^2$$

$$\text{deuterium} = {}^2_1\text{H} = \text{d} = 2.014102 \text{ u}$$

$$\text{helium-3} = {}^3_2\text{He} = 3.016029 \text{ u}$$

$$\text{proton} = {}^1_1\text{p} = \text{p} = 1.007276 \text{ u} = 938.27 \text{ MeV}/c^2$$

$$\text{hydrogen} = {}^1_1\text{H} = 1.007825 \text{ u} = 938.78 \text{ MeV}/c^2$$

$$\text{tritium} = {}^3_1\text{H} = \text{t} = 3.016049 \text{ u}$$

$$\text{helium-4} = {}^4_2\text{He} = \alpha = 4.002603 \text{ u}$$

Chapter 30 Equations

Nuclides:

$$A = N + Z, \quad (\text{mass, neutron, proton numbers})$$

$$\Delta E = [(\text{mass of parts}) - (\text{mass of nuclide})]c^2$$

$$Q = [M_{\text{parent}} - M_{\text{products}}]c^2$$

$$r = (1.2 \text{ fm}) A^{1/3} \quad (\text{nuclear radius})$$

$$(\text{binding energy})$$

$$(\text{disintegration energy})$$

Half-life and decay constant

$$N = N_0 e^{-\lambda t} \quad (\text{decay of parent nuclei})$$

$$t = \frac{-1}{\lambda} \ln(N/N_0) \quad (\text{time when } N \text{ nuclei remain})$$

$$\lambda T_{1/2} = \ln 2 \quad (\text{decay constant, half-life})$$

$$\#(^{14}_6\text{C})/\#(^{12}_6\text{C}) = 1.2 \times 10^{-12} \quad (\text{live carbon ratio})$$

$$\left| \frac{\Delta N}{\Delta t} \right| = N\lambda \quad (\text{radio-activity})$$

$$M = Nm = \text{mass} = (\# \text{ of nuclei}) \times (\text{nuclear mass})$$

$$\tau = \frac{1}{\lambda} \quad (\text{mean life time})$$

$$1 \text{ year} = 3.156 \times 10^7 \text{ seconds}$$

Chapter 31 Equations

Reactions:

$$Q = [M_{\text{reactants}} - M_{\text{products}}]c^2 \quad (\text{reaction energy})$$

$$Q > 0 \quad (Q = \text{mass converted to energy})$$

$$Q < 0 \quad (|Q| = \text{threshold energy})$$

Energy, power and mass in nuclear reactors:

$$E = mc^2 \quad (\text{Einstein's mass-energy equivalence})$$

$$E = NQ \quad [\text{energy} = (\# \text{ of reactions}) \times (\text{reaction energy})]$$

$$M = Nm \quad [\text{mass used} = (\# \text{ of reactions}) \times (\text{reaction mass})]$$

$$E_{\text{out}} = eE_{\text{in}} \quad [\text{output energy} = (\text{efficiency}) \times (\text{input energy})]$$

$$P = E/t \quad (\text{power})$$

$$1 \text{ u} \cdot c^2 = 931.5 \text{ MeV}$$