

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) All nuclei of potassium have the same number of
a. protons b. neutrons. c. nucleons. d. neurons. e. electrons.

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

 3. (2) For a stable nucleus of mass M , the total mass of its separated constituent protons and neutrons is
a. less than M . b. equal to M . c. greater than M .

 4. (2) For heavy stable nuclei (those with $A > 56$) with N neutrons and Z protons, which relation holds?
a. $Z > N$. b. $Z = N$. c. $Z < N$.

 5. (4) One uranium-238 nucleus contains _____ protons and _____ neutrons.

 6. (2) Generally speaking, which type of radiation from unstable nuclei is the least 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 less 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 uses a saturated vapor to show particle tracks?
a. Geiger counter. b. scintillation counter. c. cloud chamber. d. bubble chamber.

 11. (3) The nuclide ${}_{82}^{210}\text{Pb}$ (lead-210) can decay spontaneously by α emission. What is the daughter nucleus (give the symbol with atomic number and mass number)?
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12. (12) ${}^3_1\text{H}$ (tritium) undergoes radioactive decay by β^- emissions. Write the equation for the reaction, showing the daughter nucleus, and determine the disintegration energy per decay.

13. (3) **T F** $^{14}_6\text{C}$ is formed in the atmosphere when oxygen captures a neutron while emitting a proton.
14. (3) **T F** After two half-lives, the entire mass of a radioactive sample has decayed away.
15. (3) **T F** $^{56}_{26}\text{Fe}$ has greater binding energy per nucleon than $^{235}_{92}\text{U}$.
16. (3) **T F** In spontaneous nuclear decays, the parent's mass can be less than that of the daughter.
17. (3) **T F** Bananas and KI salt-substitute have weak radioactivity due to the isotope $^{40}_{19}\text{K}$.
18. (3) **T F** Helium-3 can decay by emitting an α -particle.

19. (8) The atomic mass of $^{23}_{11}\text{Na}$ (sodium-23) is 22.989770 u. Determine the binding energy per nucleon for the nucleus, in MeV/nucleon. (See equation sheet for neutron and other masses.)

20. (8) Another isotope of sodium is $^{24}_{11}\text{Na}$, with mass of 23.990963 u. How much energy input is required to remove one neutron from it?

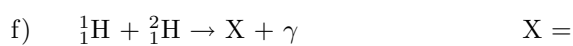
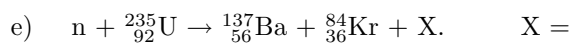
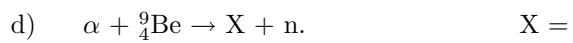
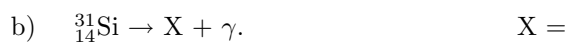
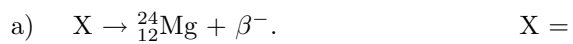
21. (18) Iodine-128 decays by β^- emission with a half-life of 26.3 minutes. At some starting time, a sample's activity is 250 decays/s. .

a) (6) How many iodine-128 nuclei are present initially in the sample?

b) (6) What mass of iodine-128 is present initially in the sample?

b) (6) How strong is the activity 2.00 hours later?

22. (18) For the reactions below find the missing symbol (with element, A and Z if appropriate):



23. (2) Nuclear reactions where small nuclei combine to form larger nuclei are called
a. fission. b. fusion. c. transmutation. d. sequestration.
24. (2) Nuclear reactions where larger nuclei split into smaller ones are called
a. fission. b. fusion. c. transmutation. d. sequestration.
25. (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.
26. (2) The main nuclear fuel that produces the Sun's energy is
a. electrons. b. hydrogen. c. helium. d. carbon. e. oxygen.
27. (2) Enriched uranium used for nuclear reactors is high in
a. uranium-92. b. uranium-235. c. uranium-236 d. uranium-238.
28. (2) The fission process can become a *chain-reaction* because fission releases
a. neutrons. b. protons. c. electrons. d. fission fragments.
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29. (18) In fission of uranium-235, the typical reaction releases approximately 200 MeV, although the exact value depends on the fission fragments. Suppose a reactor running on uranium produces a thermal power output of 5.0 MW for one year.
- a) (6) How many uranium fission reactions must take place in one year?

b) (6) How much total mass of uranium-235 fuel is needed?

c) (6) How much mass is converted to energy in one year, 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)

$$\text{electron} = {}^0_1e = 0.00054858 \text{ u} = 0.51100 \text{ MeV}/c^2$$

$$\text{neutron} = {}^1_0n = n = 1.008665 \text{ u} = 939.57 \text{ MeV}/c^2$$

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

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

$$\text{proton} = {}^1_1p = p = 1.007276 \text{ u} = 938.27 \text{ MeV}/c^2$$

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

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

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

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 $T_{1/2}$ and decay constant λ

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

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

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

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

$$N = N_0 \left(\frac{1}{2}\right)^{t/T_{1/2}} \quad (\text{decay by half-lives})$$

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

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

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

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:

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

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

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

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

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

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

Periodic Table of the Elements[§]

Group I		Group II		Transition Elements										Group III	Group IV	Group V	Group VI	Group VII	Group VIII																
H	1	Li	3	Be	4	Symbol		Atomic Mass [§]		Atomic Number		Electron Configuration		(outer shells only)		B	5	C	6	N	7	O	8	F	9	Ne	10								
1.00794	1s ¹	6.941	2s ¹	9.012182	2s ²	Cl	17	35.4527	3p ⁵							10.811	12.0107	14.00674	15.9994	18.9984032	20.1797	2p ⁴	2p ⁵	2p ⁶	18.9984032	20.1797	2p ⁶	4.002602	1s ²						
Na	11	Mg	12													Al	13	Si	14	P	15	S	16	Cl	17	Ar	18								
22.989770	3s ¹	24.3050	3s ²													26.981538	28.0855	30.973761	32.066	35.4527	39.948	3p ⁴	3p ⁵	3p ⁶	39.948	3p ⁶									
K	19	Ca	20	Sc	21	Ti	22	V	23	Cr	24	Mn	25	Fe	26	Co	27	Ni	28	Cu	29	Zn	30	Ga	31	Ge	32	As	33	Se	34	Br	35	Kr	36
39.0983	4s ¹	40.078	4s ²	44.955910	4d ¹ 4s ²	47.867	4d ² 4s ²	50.9415	4d ³ 4s ²	51.9961	4d ⁴ 4s ¹	54.938049	4d ⁵ 4s ²	55.845	4d ⁶ 4s ²	58.933200	4d ⁷ 4s ²	58.6934	4d ⁸ 4s ²	63.546	4d ⁹ 4s ¹	65.39	4d ¹⁰ 4s ²	69.723	72.61	74.92160	78.96	79.904	83.80	83.80	4p ⁵	4p ⁶	83.80		
Rb	37	Sr	38	Y	39	Zr	40	Nb	41	Mo	42	Tc	43	Ru	44	Rh	45	Pd	46	Ag	47	Cd	48	In	49	Sn	50	Sb	51	Te	52	I	53	Xe	54
85.4678	5s ¹	87.62	5s ²	88.90585	4d ¹ 5s ²	91.224	4d ² 5s ²	92.90638	4d ³ 5s ¹	95.94	4d ⁴ 5s ¹	98	4d ⁵ 5s ⁰	101.07	4d ⁶ 5s ¹	102.90550	4d ⁷ 5s ¹	106.42	4d ⁸ 5s ⁰	107.8682	4d ⁹ 5s ¹	112.411	4d ¹⁰ 5s ²	114.818	118.710	121.760	127.60	126.90447	131.29	126.90447	5p ⁵	5p ⁶	131.29		
Cs	55	Ba	56	57-71†	Hf	72	Ta	73	W	74	Re	75	Os	76	Ir	77	Pt	78	Au	79	Hg	80	Tl	81	Pb	82	Bi	83	Po	84	At	85	Rn	86	
132.90545	6s ¹	137.327	6s ²	(226)	5d ² 6s ²	178.49	5d ³ 6s ²	180.9479	5d ⁴ 6s ²	183.84	5d ⁵ 6s ²	186.207	190.23	195.078	192.217	195.078	196.96655	200.59	204.3833	207.2	208.98038	207.2	208.98038	207.2	207.2	207.2	208.98038	209	(210)	(222)	(222)	208.98038			
Fr	87	Ra	88	89-103‡	Rf	104	Db	105	Sg	106	Bh	107	Hs	108	Mt	109	Ds	110	111	112															
(223)	7s ¹	(226)	7s ²	(261)	6d ² 7s ²	6d ³ 7s ²	6d ⁴ 7s ²	6d ⁵ 7s ²	6d ⁶ 7s ²	6d ⁷ 7s ²	6d ⁸ 7s ²	6d ⁹ 7s ¹	6d ¹⁰ 7s ¹	6d ¹⁰ 7s ¹	6d ¹⁰ 7s ¹	6d ¹⁰ 7s ¹	6d ¹⁰ 7s ¹	6d ¹⁰ 7s ¹	6d ¹⁰ 7s ¹	6d ¹⁰ 7s ¹	6d ¹⁰ 7s ¹	6d ¹⁰ 7s ²	6d ¹⁰ 7s ²	6d ¹⁰ 7s ²	6d ¹⁰ 7s ²	6d ¹⁰ 7s ²	6d ¹⁰ 7s ²	6d ¹⁰ 7s ²	6d ¹⁰ 7s ²	6d ¹⁰ 7s ²	6d ¹⁰ 7s ²				
				†Lanthanide Series																															
				‡Actinide Series																															
				§ Atomic mass values averaged over isotopes in the percentages they occur on Earth's surface. For unstable elements, mass of the longest-lived known isotope is given in parentheses. 2003 revisions. (See also Appendix B.)																															