General Physics II **Exam 5 - Chs. 30, 31 - Nuclear Physics** **Dec. 13, 2016**

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 ${}^{210}_{82}\text{Pb}$ (lead-210) can decay spontaneously by α emission. What is the daughter nucleus (give the symbol with atomic number and mass number)?

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** ${}^{14}_{6}\mathrm{C}$ 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** ${}^{56}_{26}\mathrm{Fe}$ has greater binding energy per nucleon than ${}^{235}_{92}\mathrm{U}$.

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 ${}^{40}_{19}\mathrm{K}$.

18. (3) **T** **F** Helium-3 can decay by emitting an α-particle.

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19. (8) The atomic mass of ${}^{23}_{11}\mathrm{Na}$ (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.)

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20. (8) Another isotope of sodium is ${}^{24}_{11}\mathrm{Na}$, 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?

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

a) $\mathrm{X} \rightarrow {}^{24}_{12}\mathrm{Mg} + \beta^-$. X =

b) ${}^{31}_{14}\mathrm{Si} \rightarrow \mathrm{X} + \gamma$. X =

c) $\mathrm{X} \rightarrow {}^{222}_{86}\mathrm{Rn} + \alpha$. X =

d) $\alpha + {}^{9}_{4}\mathrm{Be} \rightarrow \mathrm{X} + \mathrm{n}$. X =

e) $\mathrm{n} + {}^{235}_{92}\mathrm{U} \rightarrow {}^{137}_{56}\mathrm{Ba} + {}^{84}_{36}\mathrm{Kr} + \mathrm{X}$. X =

f) ${}^{1}_{1}\mathrm{H} + {}^{2}_{1}\mathrm{H} \rightarrow \mathrm{X} + \gamma$ X =

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?

Score = ___________/137.

Prefixes

a=10^{-18}, f=10^{-15}, p=10^{-12}, n=10^{-9}, $\mu = 10^{-6}$, m=10^{-3}, c=10^{-2}, k=10^3, M=10^6, G=10^9, T=10^{12}, P=10^{15}

Physical Constants

$k = 1/4\pi\epsilon_0 = 8.988$ GN·m^2/C^2 (Coulomb's Law)
$e = 1.602 \times 10^{-19}$ C (proton charge)
$c = 3.00 \times 10^8$ m/s (speed of light)
$m_e = 9.1094 \times 10^{-31}$ kg = (electron mass)
$m_n = 1.67493 \times 10^{-27}$ kg = (neutron mass)
$h = 6.6262 \times 10^{-34}$ J·s (Planck's constant)

$\epsilon_0 = 1/4\pi k = 8.854$ pF/m (permittivity of space)
$\mu_0 = 4\pi \times 10^{-7}$ T·m/A (permeability of space)
$c = 2.99792458 \times 10^8$ m/s (exact value in vacuum)
$m_p = 1.67262 \times 10^{-27}$ kg = (proton mass)
$hc = 1240$ eV·nm (photon energy = hc/λ)
$\hbar = 1.05459 \times 10^{-34}$ J·s (Planck's constant/2π)

Units

$N_A = 6.02 \times 10^{23}$/mole (Avogadro's #)
1.0 eV = 1.602×10^{-19} J (electron-volt)
1 F = 1 farad = 1 C/V = 1 C^2/J
1 A = 1 ampere = 1 C/s = 1 coulomb/second
1 T = 1 tesla = 1 N/A·m = 1 newton/ampere·meter
1 Bq = 1 becquerel = 1 decay/s

1 u = 1 g/N_A = 1.6605×10^{-27} kg = 931.5 MeV/c^2
1 V = 1 volt = 1 J/C = 1 joule/coulomb
1 H = 1 henry = 1 V·s/A = 1 J/A^2
1 Ω = 1 ohm = 1 V/A = 1 J·s/C^2
1 G = 1 gauss = 10^{-4} T = 10^{-4} tesla
1 Ci = 1 curie = 3.70×10^{10} decays/s = 37.0 GBq

Some Masses (for neutral atoms)

electron = ${}^{0}_{-1}$e = 0.00054858 u = 0.51100 MeV/c^2
neutron = ${}^1_0$n = n = 1.008665 u = 939.57 MeV/c^2
deuterium = ${}^2_1$H = d = 2.014102 u
helium-3 = ${}^3_2$He = 3.016029 u

proton = ${}^1_1$p = p =1.007276 u = 938.27 MeV/c^2
hydrogen = ${}^1_1$H = 1.007825 u = 938.78 MeV/c^2
tritium = ${}^3_1$H = t = 3.016049 u
helium-4 = ${}^4_2$He = α = 4.002603 u

Chapter 30 Equations

Nuclides:

$A = N + Z$, (mass, neutron, proton numbers)
$\Delta E =$[(mass of parts) - (mass of nuclide)]c^2 (binding energy)
$Q = [M_{\text{parent}} - M_{\text{products}}]c^2$ (disintegration energy)
$r = (1.2 \text{ fm})\ A^{1/3}$ (nuclear radius)

Half-life $T_{1/2}$ and decay constant λ

$N = N_0 e^{-\lambda t}$ (decay of parent nuclei)
$t = \frac{-1}{\lambda} \ln(N/N_0)$ (time when N nuclei remain)
$\lambda T_{\frac{1}{2}} = \ln 2$ (decay constant, half-life)
$\#({}^{14}_{6}C)/\#({}^{12}_{6}C) = 1.2 \times 10^{-12}$ (live carbon ratio)

$N = N_0 \left(\frac{1}{2}\right)^{t/T_{1/2}}$ (decay by half-lives)
$\mathcal{A} = \left|\frac{\Delta N}{\Delta t}\right| = N\lambda$ (radio-activity)
$M = Nm$ = mass = (# of nuclei)×(nuclear mass)
1 year = 3.156×10^7 seconds

Chapter 31 Equations

Reactions:

$Q = [M_{\text{reactants}} - M_{\text{products}}]c^2$ (reaction energy)
$Q > 0$ (Q = mass converted to energy)
$Q < 0$ ($|Q|$ = threshold energy)

Energy, power and mass in nuclear reactors:

$E = mc^2$ (Einstein's mass-energy equivalence)
$E = NQ$ [energy= (# of reactions)×(reaction energy)]
$M = Nm$ [mass used= (# of reactions)×(reaction mass)]
$E_{\text{out}} = eE_{\text{in}}$ [output energy = (efficiency)×(input energy)]

$P = E/t$ (power)
$1 \text{ u} \cdot c^2 = 931.5$ MeV

Periodic Table of the Elements[§]

Symbol — Cl 17 — Atomic Number
Atomic Mass[§] — 35.4527
$3p^5$ — Electron Configuration (outer shells only)

Group I	Group II	Transition Elements										Group III	Group IV	Group V	Group VI	Group VII	Group VIII
H 1 1.00794 $1s^1$																	**He** 2 4.002602 $1s^2$
Li 3 6.941 $2s^1$	**Be** 4 9.012182 $2s^2$											**B** 5 10.811 $2p^1$	**C** 6 12.0107 $2p^2$	**N** 7 14.00674 $2p^3$	**O** 8 15.9994 $2p^4$	**F** 9 18.9984032 $2p^5$	**Ne** 10 20.1797 $2p^6$
Na 11 22.989770 $3s^1$	**Mg** 12 24.3050 $3s^2$											**Al** 13 26.981538 $3p^1$	**Si** 14 28.0855 $3p^2$	**P** 15 30.973761 $3p^3$	**S** 16 32.066 $3p^4$	**Cl** 17 35.4527 $3p^5$	**Ar** 18 39.948 $3p^6$
K 19 39.0983 $4s^1$	**Ca** 20 40.078 $4s^2$	**Sc** 21 44.955910 $3d^14s^2$	**Ti** 22 47.867 $3d^24s^2$	**V** 23 50.9415 $3d^34s^2$	**Cr** 24 51.9961 $3d^54s^1$	**Mn** 25 54.938049 $3d^54s^2$	**Fe** 26 55.845 $3d^64s^2$	**Co** 27 58.933200 $3d^74s^2$	**Ni** 28 58.6934 $3d^84s^2$	**Cu** 29 63.546 $3d^{10}4s^1$	**Zn** 30 65.39 $3d^{10}4s^2$	**Ga** 31 69.723 $4p^1$	**Ge** 32 72.61 $4p^2$	**As** 33 74.92160 $4p^3$	**Se** 34 78.96 $4p^4$	**Br** 35 79.904 $4p^5$	**Kr** 36 83.80 $4p^6$
Rb 37 85.4678 $5s^1$	**Sr** 38 87.62 $5s^2$	**Y** 39 88.90585 $4d^15s^2$	**Zr** 40 91.224 $4d^25s^2$	**Nb** 41 92.90638 $4d^45s^1$	**Mo** 42 95.94 $4d^55s^1$	**Tc** 43 (98) $4d^55s^2$	**Ru** 44 101.07 $4d^75s^1$	**Rh** 45 102.90550 $4d^85s^1$	**Pd** 46 106.42 $4d^{10}5s^0$	**Ag** 47 107.8682 $4d^{10}5s^1$	**Cd** 48 112.411 $4d^{10}5s^2$	**In** 49 114.818 $5p^1$	**Sn** 50 118.710 $5p^2$	**Sb** 51 121.760 $5p^3$	**Te** 52 127.60 $5p^4$	**I** 53 126.90447 $5p^5$	**Xe** 54 131.29 $5p^6$
Cs 55 132.90545 $6s^1$	**Ba** 56 137.327 $6s^2$	57–71†	**Hf** 72 178.49 $5d^26s^2$	**Ta** 73 180.9479 $5d^36s^2$	**W** 74 183.84 $5d^46s^2$	**Re** 75 186.207 $5d^56s^2$	**Os** 76 190.23 $5d^66s^2$	**Ir** 77 192.217 $5d^76s^2$	**Pt** 78 195.078 $5d^96s^1$	**Au** 79 196.96655 $5d^{10}6s^1$	**Hg** 80 200.59 $5d^{10}6s^2$	**Tl** 81 204.3833 $6p^1$	**Pb** 82 207.2 $6p^2$	**Bi** 83 208.98038 $6p^3$	**Po** 84 (209) $6p^4$	**At** 85 (210) $6p^5$	**Rn** 86 (222) $6p^6$
Fr 87 (223) $7s^1$	**Ra** 88 (226) $7s^2$	89–103‡	**Rf** 104 (261) $6d^27s^2$	**Db** 105 (262) $6d^37s^2$	**Sg** 106 (266) $6d^47s^2$	**Bh** 107 (264) $6d^57s^2$	**Hs** 108 (269) $6d^67s^2$	**Mt** 109 (268) $6d^77s^2$	**Ds** 110 (271) $6d^97s^1$	111 (272) $6d^{10}7s^1$	112 (277) $6d^{10}7s^2$						

†Lanthanide Series	**La** 57 138.9055 $5d^16s^2$	**Ce** 58 140.115 $4f^15d^16s^2$	**Pr** 59 140.90765 $4f^35d^06s^2$	**Nd** 60 144.24 $4f^45d^06s^2$	**Pm** 61 (145) $4f^55d^06s^2$	**Sm** 62 150.36 $4f^65d^06s^2$	**Eu** 63 151.964 $4f^75d^06s^2$	**Gd** 64 157.25 $4f^75d^16s^2$	**Tb** 65 158.92534 $4f^95d^06s^2$	**Dy** 66 162.50 $4f^{10}5d^06s^2$	**Ho** 67 164.93032 $4f^{11}5d^06s^2$	**Er** 68 167.26 $4f^{12}5d^06s^2$	**Tm** 69 168.93421 $4f^{13}5d^06s^2$	**Yb** 70 173.04 $4f^{14}5d^06s^2$	**Lu** 71 174.967 $4f^{14}5d^16s^2$
‡Actinide Series	**Ac** 89 (227.02775) $6d^17s^2$	**Th** 90 232.0381 $6d^27s^2$	**Pa** 91 (231) $5f^26d^17s^2$	**U** 92 238.0289 $5f^36d^17s^2$	**Np** 93 (237) $5f^46d^17s^2$	**Pu** 94 (244) $5f^66d^07s^2$	**Am** 95 (243) $5f^76d^07s^2$	**Cm** 96 (247) $5f^76d^17s^2$	**Bk** 97 (247) $5f^96d^07s^2$	**Cf** 98 (251) $5f^{10}6d^07s^2$	**Es** 99 (252) $5f^{11}6d^07s^2$	**Fm** 100 (257) $5f^{12}6d^07s^2$	**Md** 101 (258) $5f^{13}6d^07s^2$	**No** 102 (259) $5f^{14}6d^07s^2$	**Lr** 103 (262) $5f^{14}6d^17s^2$

[§] 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.)