Nuclei

Standard difficulty · 20 questions · 40 marks · Time: 42 minutes

Name: _____ Date: _____ Score: ____ / 40

Show your working for Sections B and C. Answers are on the last page — try every question first!

Section A — Choose the correct answer 8 × 1 = 8 marks

1. The radius of a nucleus of mass number 1 is: (R_0 = 1.2 fm)

(a) 0.6 fm **(b)** 2.4 fm **(c)** 2.2 fm **(d)** 1.2 fm

2. The ratio of the radii of nuclei of mass numbers 216 and 125 is:

(a) 216 : 125 **(b)** 5 : 6 **(c)** 6 : 5 **(d)** 46656 : 15625

3. The mass defect of a nucleus is 0.01422 u. Its binding energy is: (1 u = 931.5 MeV)

(a) 6.62 MeV **(b)** 0.13 MeV **(c)** 132.46 MeV **(d)** 13.25 MeV

4. The binding energy of $^{60}_{27}$Co is 420 MeV. Its binding energy per nucleon is:

(a) 7 MeV **(b)** 15.56 MeV **(c)** 12.73 MeV **(d)** 14 MeV

5. Nuclei with the same atomic number but different mass numbers are called:

(a) isotopes **(b)** isotones **(c)** isomers **(d)** isobars

6. The nucleus $^{4}_{2}$He contains:

(a) 3 protons and 2 neutrons **(b)** 2 protons and 2 neutrons

(c) 2 protons and 4 neutrons **(d)** 4 protons and 2 neutrons

7. The nuclei $^{16}_{8}$O and $^{23}_{11}$Na are:

(a) isotones **(b)** isotopes **(c)** none of these **(d)** isobars

8. Assertion (A): Nuclei of mass numbers 64 and 125 have the same nuclear density.
Reason (R): The nuclear force is short-ranged and charge-independent.

(a) Both A and R are true, and R is the correct explanation of A.

(b) Both A and R are true, but R is not the correct explanation of A.

(c) A is true, but R is false.

(d) A is false, but R is true.

Section B — Short answer 8 × 2 = 16 marks

9. The mass of the $^{40}_{20}$Ca nucleus is 39.9874 u. Find its mass defect, binding energy and binding energy per nucleon. (m_p = 1.00728 u, m_n = 1.00867 u, 1 u = 931.5 MeV)

10. How much energy is equivalent to 1 g of mass? How many kWh is that? (c = 3 × 10^8 m/s)

11. A reactor produces 600 MW, and each fission of U-235 releases 200 MeV. How many fissions take place each second? (1 MeV = 1.6×10^{-13} J)

12. U-236 (binding energy 7.6 MeV per nucleon) splits into two nuclei of mass numbers 117 and 119, each with 8.6 MeV per nucleon. Estimate the energy released.

13. Two deuterons ($^{2}_{1}$H, 1.11 MeV per nucleon) fuse to form a helium nucleus ($^{4}_{2}$He, 7.07 MeV per nucleon). Find the energy released.

14. A nucleus has 4 times the radius of a nucleus of mass number 4. Find its mass number, and compare the densities of the two.

15. How many nuclei are there in 18 g of cobalt-60? How many neutrons do they contain in all? (N_A = 6×10^{23} per mol)

16. Write the number of protons, neutrons and nucleons in $^{16}_{8}$O, and name one isotope of it.

Section C — Word problems — 4 × 4 = 16 marks

17. Find the binding energy and binding energy per nucleon of $^{14}_{7}$N, whose nuclear mass is 13.98859 u. Is it more or less tightly bound than ^{56}Fe (8.8 MeV per nucleon)? (m_p = 1.00728 u, m_n = 1.00867 u, 1 u = 931.5 MeV)

18. A nuclear power station makes 1000 MW of power from U-235 at 25% efficiency. Each fission releases 200 MeV. Find the number of fissions per second and the mass of U-235 used in one day. (1 MeV = 1.6 × 10^{-13} J, N_A = 6 × 10^{23} per mol)

19. In a fission, U-236 (7.7 MeV per nucleon) splits into two middle-sized nuclei of about 8.6 MeV per nucleon. Estimate the energy per fission, and the energy from the fission of 5 g of U-235 in joules. (N_A = 6 × 10^{23} per mol, 1 MeV = 1.6 × 10^{-13} J)

20. Find the radii of nuclei with mass numbers 64 and 125, the ratio of their volumes, and show that their densities are equal. (R_0 = 1.2 fm)

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Answer key

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Q	Answer	Working
1	**(d) 1.2 fm**	$R = R_0A^{(1/3)} = 1.2 \times 1$
2	**(c) 6 : 5**	$R \propto A^{(1/3)}$
3	**(d) 13.25 MeV**	BE = Δm × 931.5 MeV
4	**(a) 7 MeV**	420 ÷ 60
5	**(a) isotopes**	—
6	**(b) 2 protons and 2 neutrons**	neutrons = A − Z
7	**(c) none of these**	nothing in common
8	**(b) Both A and R are true, but R is not the correct explanation of A.**	A is true: $R^3 \propto A$, so mass/volume does not depend on A. R is true but does not explain A.
9	**Δm = 0.3316 u; BE = 308.89 MeV; 7.72 MeV per nucleon**	Δm = 20 × 1.00728 + 20 × 1.00867 − M
10	**9×10^{13} J; 2.5×10^6 kWh**	$E = mc^2 = 1 \times 10^{-3} \times 9 \times 10^{16}$; 1 kWh = 3.6×10^6 J
11	**1.875×10^{19}**	200 MeV = 3.2×10^{-11} J; $n = 600 \times 10^6 \div (3.2 \times 10^{-11})$
12	**236 MeV**	236 × (8.6 − 7.6)
13	**23.84 MeV**	4 × 7.07 − 2 × (2 × 1.11)
14	**A = 256; the densities are equal**	$R \propto A^{(1/3)}$, so A grows $4^3 = 64$ times
15	**1.8×10^{23} nuclei; 5.94×10^{24} neutrons**	18/60 mol × 6 × 10^{23}; 33 neutrons each
16	**8 protons, 8 neutrons, 16 nucleons; any oxygen nucleus with a different mass number**	A = Z + N
17	**Δm = 0.12306 u; BE = 114.63 MeV; 8.19 MeV per nucleon; less tightly bound**	BE = [Zm_p + Nm_n − M] × 931.5
18	**1.25×10^{20} per second; 4,230 g a day**	heat needed = 4 × electrical power; mass = n × 86,400 × 235/N_A
19	**212.4 MeV; 4.34×10^{11} J**	nuclei in 5 g = 5/235 × 6 × 10^{23}
20	**4.8 fm and 6 fm; volumes 64 : 125; mass is also in that ratio, so density is the same**	$V \propto R^3 \propto A$

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