Nuclear Physics

For nuclei and particles, we use this notation:

$^{A}_{Z}X$, where X is either the symbol for the element or for the particle
A = the mass number (sum of protons and neutrons)
Z = atomic number (number of protons)

For atomic nuclei, such a symbol can be pronounced and written using the name of the element and its mass number, so $^{14}_{6}C$, which is used in carbon dating, is "carbon-14". For other particles, we use the names listed in the table below (even those whose symbols *look* like atomic nuclei, such as the deuteron).

PARTICLES INVOLVED IN NUCLEAR REACTIONS

PARTICLE	MASS NUMBER	CHARGE (Atomic Number)	SYMBOL
alpha particle	4	2+	$^{4}_{2}He$ or $^{4}_{2}\alpha$
beta particle	0	1−	$^{0}_{-1}e$ or $^{0}_{-1}\beta$
deuteron	2	1+	$^{2}_{1}H$
gamma ray	0	0	$^{0}_{0}\gamma$ or γ
neutron	1	0	$^{1}_{0}n$
positron	0	1+	$^{0}_{1}e$
proton	1	1+	$^{1}_{1}H$ or $^{1}_{1}p$

BALANCING NUCLEAR EQUATIONS

In balancing nuclear equations, both the total charge (the subscript) and the total mass (the superscript) must be the same on both sides.

EXERCISES

A. Fill in the missing nucleus or particle in the following nuclear equations:

1) $^{104}_{48}Cd \rightarrow {}^{104}_{47}Ag + \_\_\_\_$

2) $\_\_\_\_ + {}^{0}_{-1}e \rightarrow {}^{54}_{24}Cr$

3) $^{47}_{20}Ca \rightarrow {}^{47}_{21}Sc + \_\_\_\_$

4) $^{220}_{86}Rn \rightarrow {}^{216}_{84}Po + \_\_\_\_$

5) $^{54}_{26}Fe + {}^{1}_{0}n \rightarrow {}^{1}_{1}H + \_\_\_\_$

6) $^{60}_{27}Co \rightarrow \gamma + \_\_\_\_$

7) $^{98}_{42}Mo + {}^{1}_{0}n \rightarrow {}^{0}_{-1}e + \_\_\_\_$

8) $^{24}_{12}Mg + {}^{2}_{1}H \rightarrow {}^{25}_{12}Mg + \_\_\_\_$

9) $^{9}_{4}Be + {}^{4}_{2}He \rightarrow {}^{12}_{6}C + \_\_\_\_$

10) $^{238}_{92}U + {}^{12}_{6}C \rightarrow {}^{246}_{98}Cf + \_\_\_\_$

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B. Write balanced equations for the following nuclear decay reactions:

1) alpha emission by $^{11}_{5}\mathrm{B}$

2) beta emission by $^{98}_{38}\mathrm{Sr}$

3) neutron absorption by $^{107}_{47}\mathrm{Ag}$

4) neutron emission by $^{88}_{35}\mathrm{Br}$

5) electron absorption by antimony-116

6) positron emission by arsenic-70

7) proton emission by potassium-41

8) beta decay by iodine-131

C. Lead-214 decays to bismuth-214. By what type of radiation is this accomplished?

D. Neptunium-237 alpha-decays to form what nucleus?

E. In 2005, Russian researchers produced two atoms of the heaviest noble gas (and the heaviest atom of any kind) known to man, ununoctium.

1) The atoms were created by bombarding californium-249 with the nucleus of a different element, producing ununoctium $(^{294}_{118}\mathrm{Uuo})$ and three neutrons. Write the equation.

2) Over the next 0.16 s, the ununoctium underwent alpha decay three times. What was the nucleus that remained?

SOLUTIONS

A. (1) $^{0}_{1}\mathrm{e}$ (2) $^{54}_{25}\mathrm{Mn}$ (3) $^{0}_{-1}\mathrm{e}$ or $^{0}_{-1}\beta$ (4) $^{4}_{2}\mathrm{He}$ or $^{4}_{2}\alpha$ (5) $^{54}_{25}\mathrm{Mn}$ (6) $^{60}_{27}\mathrm{Co}$ (7) $^{99}_{43}\mathrm{Tc}$ (8) $^{1}_{1}\mathrm{H}$ or $^{1}_{1}\mathrm{p}$ (9) $^{1}_{0}\mathrm{n}$ (10) $4\,^{1}_{0}\mathrm{n}$

B. (1) $^{11}_{5}\mathrm{B} \rightarrow {}^{4}_{2}\alpha + {}^{7}_{3}\mathrm{Li}$ (2) $^{98}_{38}\mathrm{Sr} \rightarrow {}^{0}_{-1}\beta + {}^{98}_{39}\mathrm{Y}$ (3) $^{107}_{47}\mathrm{Ag} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{108}_{47}\mathrm{Ag}$ (4) $^{88}_{35}\mathrm{Br} \rightarrow {}^{1}_{0}\mathrm{n} + {}^{87}_{35}\mathrm{Br}$ (5) $^{116}_{51}\mathrm{Sb} + {}^{0}_{-1}\mathrm{e} \rightarrow {}^{116}_{50}\mathrm{Sn}$ (6) $^{70}_{33}\mathrm{As} \rightarrow {}^{0}_{1}\mathrm{e} + {}^{70}_{32}\mathrm{Ge}$ (7) $^{41}_{19}\mathrm{K} \rightarrow {}^{1}_{1}\mathrm{p} + {}^{40}_{18}\mathrm{Ar}$ (8) $^{131}_{53}\mathrm{I} \rightarrow {}^{0}_{-1}\mathrm{e} + {}^{131}_{54}\mathrm{Xe}$

C. beta radiation D. protactinium-233 $(^{233}_{91}\mathrm{Pa})$ E.(1) $^{249}_{98}\mathrm{Cf} + {}^{48}_{20}\mathrm{Ca} \rightarrow {}^{294}_{118}\mathrm{Uuo} + 3\,{}^{1}_{0}\mathrm{n}$ (2) ununbium-282 $(^{282}_{112}\mathrm{Uub})$ or copernicium-282 $(^{282}_{112}\mathrm{Cn})$