5.3 BALANCING NUCLEAR EQUATIONS

PRACTICE

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Understanding Concepts

1. (a) A chemical reaction involves change in electron arrangements about nuclei, while nuclear reactions involve changes within the nuclei.
   (b) Radioactive decay involves the emission of an alpha and/or beta particle from a nucleus. Transmutation describes the changing of the original nucleus to that of a new element by this process.
   (c) Alpha decay involves the emission of an alpha particle (helium-4 nucleus) from an atomic nucleus, while beta decay involves the emission of a beta particle (electron) from a nucleus.
2. A gamma ray is a high-energy electromagnetic photon emitted during radioactive decay. Since it is energy, not matter, it is sometimes not shown in a nuclear equation.
3. $^{230}_{90}\mathrm{Th} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{226}_{88}\mathrm{Ra}$
4. $^{231}_{90}\mathrm{Th} \rightarrow {}^{0}_{-1}\mathrm{e} + {}^{231}_{91}\mathrm{Pa}$
5. $^{93}_{38}\mathrm{Sr} \rightarrow {}^{0}_{-1}\mathrm{e} + {}^{93}_{39}\mathrm{Y}$
6. $^{214}_{84}\mathrm{Po} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{210}_{82}\mathrm{Pb}$

   $^{210}_{82}\mathrm{Pb} \rightarrow {}^{0}_{-1}\mathrm{e} + {}^{210}_{83}\mathrm{Bi}$

Making Connections

7. A typical report might discuss carbon-14 dating of ancient objects that were living things (such as bones, or objects made of wood), by the decrease in radioactivity over time. This process has been of great value to archaeologists and historians in dating periods of human civilization.

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Understanding Concepts

8. Radioactive decay involves the spontaneous emission of an alpha and/or beta particle from a nucleus. Artificial transmutation describes the changing of an original nucleus to that of a new element by bombardment of the original nuclei with small nuclear particles at very high speed.
9. $^{9}_{4}\mathrm{Be} + {}^{4}_{2}\mathrm{He} \rightarrow {}^{12}_{6}\mathrm{C} + {}^{1}_{0}\mathrm{n}$
10. $^{238}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{239}_{92}\mathrm{U}$

Making Connections

11. TRIUMF is a joint venture of many of Canada's foremost universities. It is Canada's national laboratory for particle and nuclear physics research. A typical report might involve research into using beams of protons to treat cancerous eye tumours, or using particle beams to detect explosives hidden in luggage.

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Understanding Concepts

12. The fission of a uranium nucleus can be caused by a single neutron, but always releases either two or three neutrons, which, under the right conditions, can cause further fissions to create a continuous process called a chain reaction.
13. Fusion will occur only if the particles collide at extremely high speed — hence, at very high temperature.
14. $2\,{}^{3}_{2}He \rightarrow 2\,{}^{1}_{1}p + {}^{4}_{2}He$ The other particle is an alpha particle.
15. The operation of CANDU reactors involves fission of uranium. There are a huge number of nuclear reactions going on at any given moment, but the basic energy production is U-235 fission. A typical fission example follows:
    ${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{92}_{36}Kr + {}^{141}_{56}Ba + 3\,{}^{1}_{0}n$

Making Connections

16. A report should emphasize that a nuclear plant is specifically designed to produce heat energy. Controlling the heat produced requires large volumes of cooling water, so warm water is discharged in large quantity into a nearby lake, ocean, or river. This is thermal "pollution" if it causes unwanted effects in the environment.
17. A report might include information about the formation of AECL in 1952 as a Crown corporation to coordinate Canada's nuclear processes and policies; the cooperation in 1954 of AECL, Ontario Hydro, and Canadian General Electric to eventually develop the NPD power reactor at Rolphton, Ontario; the subsequent development and installation of CANDU reactors worldwide; and the research, medical, and fuel storage programs and equipment developed and marketed by AECL.

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SECTION 5.3 QUESTIONS

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Understanding Concepts

1. Nuclear reactions often involve a change in the number of protons in a nucleus, thus changing the element.
2. Fission is a nuclear reaction involving the splitting of a larger nucleus into two or more smaller nuclei.
3. (a) ${}^{226}_{88}Ra \rightarrow {}^{4}_{2}He + {}^{222}_{86}Rn$

   (b) ${}^{84}_{35}Br \rightarrow {}^{4}_{2}He + {}^{80}_{33}As$

   (c) ${}^{242}_{94}Pu \rightarrow {}^{4}_{2}He + {}^{240}_{92}U$

   (d) ${}^{14}_{7}N + {}^{1}_{1}p \rightarrow {}^{4}_{2}He + {}^{11}_{6}C$

   (e) ${}^{18}_{8}O + {}^{1}_{0}n \rightarrow {}^{0}_{-1}e + {}^{19}_{9}F$

4. (a) ${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{147}_{59}Pr + {}^{86}_{33}As + 3\,{}^{1}_{0}n$

   (b) This is a nuclear fission reaction.
5. (a) ${}^{31}_{15}P + {}^{1}_{1}p \rightarrow {}^{28}_{14}Si + {}^{4}_{2}He$ artificial transmutation

   (b) ${}^{27}_{13}Al + {}^{4}_{2}He \rightarrow {}^{30}_{14}Si + {}^{1}_{1}P$ artificial transmutation

   (c) ${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{90}_{37}Rb + {}^{144}_{55}Cs + 2\,{}^{1}_{0}n$ fission

   (d) ${}^{12}_{5}B \rightarrow {}^{12}_{6}C + {}^{0}_{-1}e$ beta decay

   (e) ${}^{228}_{90}Th \rightarrow {}^{224}_{88}Ra + {}^{4}_{2}He$ alpha decay

   (f) $2\,{}^{3}_{1}H \rightarrow {}^{4}_{2}He + 2\,{}^{1}_{0}n$ fusion

6. (a) ${}^{32}_{16}S + {}^{1}_{0}n \rightarrow {}^{32}_{15}P + {}^{1}_{1}p$

   (b) ${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{135}_{54}Xe + {}^{99}_{38}Sr + 2\,{}^{1}_{0}n$

(c) $^{187}_{75}\text{Re} \rightarrow ^{187}_{76}\text{Os} + ^{0}_{-1}\text{e}$

(d) $^{11}_{5}\text{B} + ^{1}_{1}\text{p} \rightarrow 3\ ^{4}_{2}\text{He}$

(e) $^{98}_{42}\text{Mo} + ^{2}_{1}\text{H} \rightarrow ^{99}_{43}\text{Tc} + ^{1}_{0}\text{n}$

7. The mass number drops by 28, and only alpha decay drops the mass number, and each alpha particle is 4, so 7 alpha particles are emitted. The atomic number drops by 10, which is 4 less than the drop of 14 caused by the alpha decays, so there must be 4 beta particles emitted, because each one raises the atomic number by 1.

Making Connections

8. A typical report would include information on directing a particle beam through the body to cause maximum damage at a tumour location — and probably on the development of the "cobalt bomb" cobalt-60 cancer therapy machines by AECL, and the extensive worldwide use of this treatment program.

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5.4 CALCULATING MASSES OF REACTANTS AND PRODUCTS

PRACTICE

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Understanding Concepts

1. $2\ Al_2O_{3(s)} \rightarrow 3\ O_{2(g)} + 4\ Al_{(s)}$

$2\ Al_2O_{3(s)}$	$\rightarrow$ $3\ O_{2(g)}$	+	$4\ Al_{(s)}$
125 g			m
101.96 g/mol			26.98 g/mol

$$n_{Al_2O_3} = 125\ \cancel{g} \times \frac{1\ \text{mol}}{101.96\ \cancel{g}}$$

$$n_{Al_2O_3} = 1.23\ \text{mol}$$

$$n_{Al} = 1.23\ \text{mol} \times \frac{4}{2}$$

$$n_{Al} = 2.45\ \text{mol}$$

$$m_{Al} = 2.45\ \cancel{\text{mol}} \times \frac{26.98\ \text{g}}{1\ \cancel{\text{mol}}}$$

$$m_{Al} = 66.2\ \text{g}$$

or

$$m_{Al} = 125\ \cancel{\text{g Al}_2\text{O}_3} \times \frac{1\ \cancel{\text{mol Al}_2\text{O}_3}}{101.96\ \cancel{\text{g Al}_2\text{O}_3}} \times \frac{4\ \cancel{\text{mol Al}}}{2\ \cancel{\text{mol Al}_2\text{O}_3}} \times \frac{26.98\ \text{g Al}}{1\ \cancel{\text{mol Al}}}$$

$$m_{Al} = 66.2\ \text{g}$$

The (maximum) mass of aluminum that can be produced is 66.2 g.

2. $C_3H_{8(g)} + 5\ O_{2(g)} \rightarrow 3\ CO_{2(g)} + 4\ H_2O_{(g)}$

$C_3H_{8(g)}$	+ $5\ O_{2(g)}$	$\rightarrow$ $3\ CO_{2(g)}$	+ $4\ H_2O_{(g)}$
10.0 g	m		
44.11 g/mol	32.00 g/mol		

$$n_{C_3H_8} = 10.0\ \cancel{g} \times \frac{1\ \text{mol}}{44.11\ \cancel{g}}$$

$$n_{C_3H_8} = 0.227\ \text{mol}$$

$$n_{O_2} = 0.227\ \text{mol} \times \frac{5}{1}$$

$$n_{O_2} = 1.13\ \text{mol}$$

$$m_{O_2} = 1.13\ \cancel{\text{mol}} \times \frac{32.00\ \text{g}}{1\ \cancel{\text{mol}}}$$