NAME ______________________ DATE ____________ CLASS ______________

Subatomic Physics

Problem B

NUCLEAR DECAY

PROBLEM

Bromine-80 decays by emitting a positron and a neutino. Write the complete decay formula for this process.

SOLUTION

Given: The decay can be written symbolically as follows:

$^{80}_{35}\mathrm{Br} \rightarrow \mathrm{X} + {}^{0}_{1}\mathrm{e} + \nu$

Unknown: the daughter element (X)

The mass numbers and atomic numbers on the two sides of the expression must be the same so that both charge and nucleon number are conserved during the course of a particular decay.

Mass number of X = 80 − 0 = 80

Atomic number of X = 35 − (1) = 34

$^{80}_{35}\mathrm{Br} \rightarrow {}^{80}_{34}\mathrm{X} + {}^{0}_{1}\mathrm{e} + \nu$

The periodic table (Appendix F) shows that the nucleus with an atomic number of 34 is selenium, Se. Thus, the process is as follows:

$^{80}_{35}\mathrm{Br} \rightarrow {}^{80}_{34}\mathrm{Se} + {}^{0}_{1}\mathrm{e} + \nu$

ADDITIONAL PRACTICE

1. Complete this radioactive-decay formula: $^{210}_{84}\mathrm{Po} \rightarrow ? + {}^{4}_{2}\mathrm{He}$
2. Complete this radioactive-decay formula: $^{16}_{7}\mathrm{N} \rightarrow ? + {}^{0}_{-1}\mathrm{e} + \overline{\nu}$
3. Complete this radioactive-decay formula: $^{147}_{62}\mathrm{Sm} \rightarrow {}^{143}_{60}\mathrm{Nd} + ?$
4. Complete this radioactive-decay formula: $^{19}_{10}\mathrm{Ne} \rightarrow ? + {}^{0}_{1}\mathrm{e} + \overline{\nu}$
5. Complete this radioactive-decay formula: $? \rightarrow {}^{131}_{54}\mathrm{Xe} + {}^{0}_{-1}\mathrm{e} + \overline{\nu}$
6. Complete this radioactive-decay formula: $? \rightarrow {}^{90}_{39}\mathrm{Y} + {}^{0}_{-1}\mathrm{e} + \overline{\nu}$
7. Complete this radioactive-decay formula: $^{160}_{74}\mathrm{W} \rightarrow {}^{156}_{72}\mathrm{Hf} + ?$
8. Complete this radioactive-decay formula: $? \rightarrow {}^{107}_{52}\mathrm{Te} + {}^{4}_{2}\mathrm{He}$
9. Complete this radioactive-decay formula: $^{157}_{72}\mathrm{Hf} \rightarrow {}^{153}_{70}\mathrm{Yb} + ?$
10. Complete this radioactive-decay formula: $^{141}_{58}\mathrm{Ce} \rightarrow ? + {}^{0}_{-1}\mathrm{e} + \overline{\nu}$

Givens	*Solutions*
8. $A = 64$	$N = A - Z = 64 - 30 = 34$
$Z = 30$	$\Delta m = Z(\text{atomic mass of H}) + Nm_n - \text{atomic mass of zinc-64}$
atomic mass of zinc-64 = 63.929 144 u	$\Delta m = 30(1.007\ 825\ \text{u}) + 34(1.008\ 665\ \text{u}) - 63.929\ 144\ \text{u}$
atomic mass of H = 1.007 825 u	$\Delta m = 30.234\ 750\ \text{u} + 34.294\ 610\ \text{u} - 63.929\ 144\ \text{u}$
$m_n = 1.008\ 665\ \text{u}$	$\Delta m = \boxed{0.600\ 216\ \text{u}}$

9. $A = 90$	$N = A - Z = 90 - 40 = 50$
$Z = 40$	$\Delta m = Z(\text{atomic mass of H}) + Nm_n - \text{atomic mass of zirconium-90}$
atomic mass of zirconium-90 = 89.904 702 u	$\Delta m = 40(1.007\ 825\ \text{u}) + 50(1.008\ 665\ \text{u}) - 89.904\ 702\ \text{u}$
atomic mass of H = 1.007 825 u	$\Delta m = 40.313\ 000\ \text{u} + 50.433\ 250\ \text{u} - 89.904\ 702\ \text{u}$
$m_n = 1.008\ 665\ \text{u}$	$\Delta m = 0.841\ 548\ \text{u}$
	$E_{bind} = (0.841\ 548\ \text{u})(931.49\ \text{MeV/u}) = \boxed{783.89\ \text{MeV}}$

10. $A = 32$	$N = A - Z = 32 - 16 = 16$
$Z = 16$	$\Delta m = Z(\text{atomic mass of H}) + Nm_n - \text{atomic mass of sulfur-32}$
atomic mass of sulfur-32 = 31.972 071 u	$\Delta m = 16(1.007\ 825\ \text{u}) + 16(1.008\ 665\ \text{u}) - 31.972\ 071\ \text{u}$
atomic mass of H = 1.007 825 u	$\Delta m = 16.125\ 200\ \text{u} + 16.138\ 640\ \text{u} - 31.972\ 071\ \text{u}$
$m_n = 1.008\ 665\ \text{u}$	$\Delta m = \boxed{0.291\ 769\ \text{u}}$

Additional Practice B

1. $^{210}_{84}\text{Po} \rightarrow ? + ^{4}_{2}\text{He}$	$A = 210 - 4 = 206$
	$Z = 84 - 2 = 82$
	$? = \boxed{^{206}_{82}\text{Pb}}$
2. $^{16}_{7}\text{N} \rightarrow ? + ^{0}_{-1}\text{e} + \overline{\nu}$	$A = 16 - 0 = 16$
	$Z = 7 - (-1) = 8$
	$? = \boxed{^{16}_{8}\text{O}}$
3. $^{147}_{62}\text{Sm} \rightarrow ^{143}_{60}\text{Nd} + ? + \overline{\nu}$	$A = 147 - 143 = 4$
	$Z = 62 - 60 = 2$
	$? = \boxed{^{4}_{2}\text{He}}$
4. $^{19}_{10}\text{Ne} \rightarrow ? + ^{0}_{1}\text{e} + \overline{\nu}$	$A = 19 - 0 = 19$
	$Z = 10 - 1 = 9$
	$? = \boxed{^{19}_{9}\text{F}}$

Givens | *Solutions*

5. $? \rightarrow {}^{131}_{54}\mathrm{Xe} + {}^{0}_{-1}e + \overline{\nu}$

$A = 131 + 0 = 131$

$Z = 54 + (-1) = 53$

$? = \boxed{{}^{131}_{53}\mathrm{I}}$

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6. $? \rightarrow {}^{90}_{39}\mathrm{Y} + {}^{0}_{-1}e + \overline{\nu}$

$A = 90 + 0 = 90$

$Z = 39 + (-1) = 38$

$? = \boxed{{}^{90}_{38}\mathrm{Sr}}$

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7. ${}^{160}_{74}\mathrm{W} \rightarrow {}^{156}_{72}\mathrm{Hf} + ?$

$A = 160 - 156 = 4$

$Z = 74 - 72 = 2$

$? = \boxed{{}^{4}_{2}\mathrm{He}}$

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8. $? \rightarrow {}^{107}_{52}\mathrm{Te} + {}^{4}_{2}\mathrm{He}$

$A = 107 + 4 = 111$

$Z = 52 + 2 = 54$

$? = \boxed{{}^{111}_{54}\mathrm{Xe}}$

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9. ${}^{157}_{72}\mathrm{Hf} \rightarrow {}^{153}_{70}\mathrm{Yb} + ?$

$A = 157 - 153 = 4$

$Z = 72 - 70 = 2$

$? = \boxed{{}^{4}_{2}\mathrm{He}}$

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10. ${}^{141}_{58}\mathrm{Ce} \rightarrow ? + {}^{0}_{-1}e + \overline{\nu}$

$A = 141 - 0 = 141$

$Z = 58 - (-1) = 59$

$? = \boxed{{}^{141}_{59}\mathrm{Pr}}$

Additional Practice C

1. $m_i = 5.25 \times 10^{-3}$ g

$m_f = 3.28 \times 10^{-4}$ g

$\Delta t = 12$ h

$$\frac{m_f}{m_i} = \frac{3.28 \times 10^{-4}\ \mathrm{g}}{5.25 \times 10^{-3}\ \mathrm{g}} = \frac{1}{16}$$

If $\frac{1}{16}$ of the sample remains after 12 h, then $\frac{1}{8}$ of the sample must have remained after 6.0 h, $\frac{1}{4}$ of the sample must have remained after 3.0 h, and $\frac{1}{2}$ of the sample must have remained after 1.5 h. So $T_{1/2} = \boxed{1.5\ \mathrm{h}}$

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2. $m_i = 3.29 \times 10^{-3}$ g

$m_f = 8.22 \times 10^{-4}$ g

$\Delta t = 30.0$ s

$$\frac{m_f}{m_i} = \frac{8.22 \times 10^{-4}\ \mathrm{g}}{3.29 \times 10^{-3}\ \mathrm{g}} = \frac{1}{4}$$

If $\frac{1}{4}$ of the sample remains after 30.0 s, then $\frac{1}{2}$ of the sample must have remained after 15.0 s, so $T_{1/2} = \boxed{15.0\ \mathrm{s}}$.

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3. $m_i = 4.14 \times 10^{-4}$ g

$m_f = 2.07 \times 10^{-4}$ g

$\Delta t = 1.25$ days

$$\frac{m_f}{m_i} = \frac{2.07 \times 10^{-4}\ \mathrm{g}}{4.14 \times 10^{-4}\ \mathrm{g}} = \frac{1}{2}$$

If $\frac{1}{2}$ of the sample remains after 1.25 days, then $T_{1/2} = \boxed{1.25\ \mathrm{days}}$