Chapter 6
HESS'S LAW PRACTICE
(1) Find the $\Delta \mathrm{H}$ for the reaction below, given the following reactions and subsequent $\Delta \mathrm{H}$ values:
$\mathrm{PCl}_{5}(\mathrm{~g}) \rightarrow \mathrm{PCl}_{3}(\mathrm{~g})+\mathrm{Cl}_{2}(\mathrm{~g})$
$\mathrm{P}_{4}(\mathrm{~s})+6 \mathrm{Cl}_{2}(\mathrm{~g}) \rightarrow 4 \mathrm{PCl}_{3}(\mathrm{~g}) \quad \Delta \mathrm{H}=-2439 \mathrm{~kJ}$
$4 \mathrm{PCl}_{5}(\mathrm{~g}) \rightarrow \mathrm{P}_{4}(\mathrm{~s})+10 \mathrm{Cl}_{2}(\mathrm{~g}) \quad \Delta \mathrm{H}=3438 \mathrm{~kJ}$
(2) Find the $\Delta \mathrm{H}$ for the reaction below, given the following reactions and subsequent $\Delta \mathrm{H}$ values:

$$
2 \mathrm{CO}_{2}(\mathrm{~g})+\mathrm{H}_{2} \mathrm{O}(\mathrm{~g}) \rightarrow \mathrm{C}_{2} \mathrm{H}_{2}(\mathrm{~g})+5 / 2 \mathrm{O}_{2}(\mathrm{~g})
$$

$\mathrm{C}_{2} \mathrm{H}_{2}(\mathrm{~g})+2 \mathrm{H}_{2}(\mathrm{~g}) \rightarrow \mathrm{C}_{2} \mathrm{H}_{6}(\mathrm{~g})$
$\Delta \mathrm{H}=-94.5 \mathrm{~kJ}$
$\mathrm{H}_{2} \mathrm{O}(\mathrm{g}) \rightarrow \mathrm{H}_{2}(\mathrm{~g})+1 / 2 \mathrm{O}_{2}(\mathrm{~g})$
$\Delta \mathrm{H}=71.2 \mathrm{~kJ}$
$\mathrm{C}_{2} \mathrm{H}_{6}(\mathrm{~g})+7 / 2 \mathrm{O}_{2}(\mathrm{~g}) \rightarrow 2 \mathrm{CO}_{2}(\mathrm{~g})+3 \mathrm{H}_{2} \mathrm{O}(\mathrm{g})$
$\Delta \mathrm{H}=-283 \mathrm{~kJ}$
(3) Find the $\Delta \mathrm{H}$ for the reaction below, given the following reactions and subsequent $\Delta \mathrm{H}$ values:
$\mathrm{N}_{2} \mathrm{H}_{4}(\mathrm{l})+\mathrm{H}_{2}(\mathrm{~g}) \rightarrow 2 \mathrm{NH}_{3}(\mathrm{~g})$
$\mathrm{N}_{2} \mathrm{H}_{4}(\mathrm{l})+\mathrm{CH}_{4} \mathrm{O}(\mathrm{l}) \rightarrow \mathrm{CH}_{2} \mathrm{O}(\mathrm{g})+\mathrm{N}_{2}(\mathrm{~g})+3 \mathrm{H}_{2}(\mathrm{~g})$
$\Delta \mathrm{H}=-37 \mathrm{~kJ}$
$\mathrm{N}_{2}(\mathrm{~g})+3 \mathrm{H}_{2}(\mathrm{~g}) \rightarrow 2 \mathrm{NH}_{3}(\mathrm{~g})$
$\Delta \mathrm{H}=-46 \mathrm{~kJ}$
$\mathrm{CH}_{4} \mathrm{O}(\mathrm{l}) \rightarrow \mathrm{CH}_{2} \mathrm{O}(\mathrm{g})+\mathrm{H}_{2}(\mathrm{~g})$ $\Delta \mathrm{H}=-65 \mathrm{~kJ}$
(4) Find the $\Delta \mathrm{H}$ for the reaction below, given the following reactions and subsequent $\Delta \mathrm{H}$ values:

$$
\mathrm{H}_{2} \mathrm{SO}_{4}(\mathrm{l}) \rightarrow \mathrm{SO}_{3}(\mathrm{~g})+\mathrm{H}_{2} \mathrm{O}(\mathrm{~g})
$$

| $\mathrm{H}_{2} \mathrm{~S}(\mathrm{~g})+2 \mathrm{O}_{2}(\mathrm{~g}) \rightarrow \mathrm{H}_{2} \mathrm{SO}_{4}(\mathrm{l})$ | $\Delta \mathrm{H}=-235.5 \mathrm{~kJ}$ |
| :--- | :--- |
| $\mathrm{H}_{2} \mathrm{~S}(\mathrm{~g})+2 \mathrm{O}_{2}(\mathrm{~g}) \rightarrow \mathrm{SO}_{3}(\mathrm{~g})+\mathrm{H}_{2} \mathrm{O}(\mathrm{l})$ | $\Delta \mathrm{H}=-207 \mathrm{~kJ}$ |
| $\mathrm{H}_{2} \mathrm{O}(\mathrm{l}) \rightarrow \mathrm{H}_{2} \mathrm{O}(\mathrm{g})$ | $\Delta \mathrm{H}=44 \mathrm{~kJ}$ |

(5) Find the $\Delta \mathrm{H}$ for the reaction below, given the following reactions and subsequent $\Delta \mathrm{H}$ values:
$2 \mathrm{C}_{2} \mathrm{H}_{4} \mathrm{O}(\mathrm{l})+2 \mathrm{H}_{2} \mathrm{O}(\mathrm{l}) \rightarrow 2 \mathrm{C}_{2} \mathrm{H}_{6} \mathrm{O}(\mathrm{l})+\mathrm{O}_{2}(\mathrm{~g})$
$\mathrm{C}_{2} \mathrm{H}_{6} \mathrm{O}(\mathrm{l})+3 \mathrm{O}_{2}(\mathrm{~g}) \rightarrow 2 \mathrm{CO}_{2}(\mathrm{~g})+3 \mathrm{H}_{2} \mathrm{O}(\mathrm{l}) \quad \Delta \mathrm{H}=-685.5 \mathrm{~kJ}$
$\mathrm{C}_{2} \mathrm{H}_{4} \mathrm{O}(\mathrm{l})+5 / 2 \mathrm{O}_{2}(\mathrm{~g}) \rightarrow 2 \mathrm{CO}_{2}(\mathrm{~g})+2 \mathrm{H}_{2} \mathrm{O}(\mathrm{l}) \quad \Delta \mathrm{H}=-583.5 \mathrm{~kJ}$
(6) Find the $\Delta \mathrm{H}$ for the reaction below, given the following reactions and subsequent $\Delta \mathrm{H}$ values:

$$
\begin{array}{ll}
\mathrm{N}_{2}(\mathrm{~g})+2 \mathrm{O}_{2}(\mathrm{~g}) \rightarrow 2 \mathrm{NO}_{2}(\mathrm{~g}) & \\
& \Delta \mathrm{H}=-115 \mathrm{~kJ} \\
\mathrm{~N}_{2}(\mathrm{~g})+3 \mathrm{H}_{2}(\mathrm{~g}) \rightarrow 2 \mathrm{NH}_{3}(\mathrm{~g}) & \Delta \mathrm{H}=-142.5 \mathrm{~kJ} \\
2 \mathrm{NH}_{3}(\mathrm{~g})+4 \mathrm{H}_{2} \mathrm{O}(\mathrm{l}) \rightarrow 2 \mathrm{NO}_{2}(\mathrm{~g})+7 \mathrm{H}_{2}(\mathrm{~g}) & \Delta \mathrm{H}=-43.7 \mathrm{~kJ} \\
\mathrm{H}_{2} \mathrm{O}(\mathrm{l}) \rightarrow \mathrm{H}_{2}(\mathrm{~g})+1 / 2 \mathrm{O}_{2}(\mathrm{~g}) & \Delta \mathrm{H}=-4
\end{array}
$$

(7) Find the $\Delta \mathrm{H}$ for the reaction below, given the following reactions and subsequent $\Delta \mathrm{H}$ values:

$$
\mathrm{CO}_{2}(\mathrm{~g}) \rightarrow \mathrm{C}(\mathrm{~s})+\mathrm{O}_{2}(\mathrm{~g})
$$

$\mathrm{H}_{2} \mathrm{O}(\mathrm{l}) \rightarrow \mathrm{H}_{2}(\mathrm{~g})+1 / 2 \mathrm{O}_{2}(\mathrm{~g})$

$$
\mathrm{C}_{2} \mathrm{H}_{6}(\mathrm{~g}) \rightarrow 2 \mathrm{C}(\mathrm{~s})+3 \mathrm{H}_{2}(\mathrm{~g})
$$

$$
2 \mathrm{CO}_{2}(\mathrm{~g})+3 \mathrm{H}_{2} \mathrm{O}(\mathrm{l}) \rightarrow \mathrm{C}_{2} \mathrm{H}_{6}(\mathrm{~g})+7 / 2 \mathrm{O}_{2}(\mathrm{~g})
$$

$$
\begin{aligned}
& \Delta \mathrm{H}=643 \mathrm{~kJ} \\
& \Delta \mathrm{H}=190.6 \mathrm{~kJ} \\
& \Delta \mathrm{H}=3511.1 \mathrm{~kJ}
\end{aligned}
$$

(8) Find the $\Delta H$ for the reaction below, given the following reactions and subsequent $\Delta H$ values:

$$
\mathrm{N}_{2} \mathrm{H}_{4}(\mathrm{l})+\mathrm{CH}_{4} \mathrm{O}(\mathrm{l}) \rightarrow \mathrm{CH}_{2} \mathrm{O}(\mathrm{~g})+\mathrm{N}_{2}(\mathrm{~g})+3 \mathrm{H}_{2}(\mathrm{~g})
$$

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2NH3}(\textrm{g})->\mp@subsup{\textrm{N}}{2}{}\mp@subsup{\textrm{H}}{4}{}(\textrm{l})+\mp@subsup{\textrm{H}}{2}{}(\textrm{g}
2NH3}(\textrm{g})->\mp@subsup{\textrm{N}}{2}{}(\textrm{g})+3\mp@subsup{\textrm{H}}{2}{(g)
    \DeltaH}=22.5\textrm{kJ
    \DeltaH}=57.5\textrm{kJ
CH2O(g)}+\mp@subsup{\textrm{H}}{2}{}(\textrm{g})->\mp@subsup{\textrm{CH}}{4}{}\textrm{O}(\textrm{l}
    \DeltaH=81.2 kJ
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(9) Find the $\Delta H$ for the reaction below, given the following reactions and subsequent $\Delta H$ values:

$$
1 / 2 \mathrm{H}_{2}(\mathrm{~g})+1 / 2 \mathrm{Cl}_{2}(\mathrm{~g}) \rightarrow \mathrm{HCl}(\mathrm{~g})
$$

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COCl}(\textrm{g})+\mp@subsup{\textrm{H}}{2}{}\textrm{O}(\textrm{l})->\mp@subsup{\textrm{CH}}{2}{}\mp@subsup{\textrm{Cl}}{2}{}(\textrm{l})+\mp@subsup{\textrm{O}}{2}{}(\textrm{g}
2HCl(g) + 1/2O2(g) -> H2O(l)}+\mp@subsup{\textrm{Cl}}{2}{}(\textrm{g}
CH2Cl2 (l)}+\mp@subsup{\textrm{H}}{2}{}(\textrm{g})+3/2\mp@subsup{\textrm{O}}{2}{2}(\textrm{g})->\mp@subsup{\textrm{COCl}}{2}{}(\textrm{g})+2\mp@subsup{\textrm{H}}{2}{}\textrm{O}(\textrm{l}
\DeltaH=47.5 kJ
\DeltaH=105 kJ
(10) Find the \(\Delta \mathrm{H}\) for the reaction below, given the following reactions and subsequent \(\Delta \mathrm{H}\) values:
\[
\mathrm{C}_{2} \mathrm{H}_{2}(\mathrm{~g})+5 / 2 \mathrm{O}_{2}(\mathrm{~g}) \rightarrow 2 \mathrm{CO}_{2}(\mathrm{~g})+\mathrm{H}_{2} \mathrm{O}(\mathrm{~g})
\]
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C2}\mp@subsup{\textrm{H}}{6}{}(\textrm{g})->\mp@subsup{\textrm{C}}{2}{}\mp@subsup{\textrm{H}}{2}{}(\textrm{g})+2\mp@subsup{\textrm{H}}{2}{}(\textrm{g}
\DeltaH=283.5 kJ
H2}(\textrm{g})+1/2\mp@subsup{\textrm{O}}{2}{}(\textrm{g})->\mp@subsup{\textrm{H}}{2}{}\textrm{O}(\textrm{g}
\Delta \mathrm { H } = - 2 1 3 . 7 \mathrm { kJ }
2CO2(g)+3\mp@subsup{H}{2}{\primeO}(\textrm{g})->\mp@subsup{\textrm{C}}{2}{}\mp@subsup{\textrm{H}}{6}{}(\textrm{g})+7/2\mp@subsup{\textrm{O}}{2}{}(\textrm{g})\quad\DeltaH=849\textrm{kJ}

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(11) Find the \(\Delta \mathrm{H}\) for the reaction below, given the following reactions and subsequent \(\Delta \mathrm{H}\) values:
\[
\mathrm{HCl}(\mathrm{~g})+\mathrm{NaNO}_{2}(\mathrm{~s}) \rightarrow \mathrm{HNO}_{2}(\mathrm{l})+\mathrm{NaCl}(\mathrm{~s})
\]
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2NaCl(s)+ + +
NO}(\textrm{g})+\mp@subsup{\textrm{NO}}{2}{}(\textrm{g})+\mp@subsup{\textrm{Na}}{2}{}\textrm{O}(\textrm{s})->2\mp@subsup{\textrm{NaNO}}{2}{}(\textrm{s}
NO(g)+ NO2 (g) -> N}\mp@subsup{\textrm{N}}{2}{}\textrm{O}(\textrm{g})+\mp@subsup{\textrm{O}}{2}{}(\textrm{g}
2HNO
\DeltaH=507 kJ
\DeltaH=-427 kJ
\Delta H = - 4 3 \mathrm { kJ }
\Delta H = 3 4 k J

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(12) Find the \(\Delta \mathrm{H}\) for the reaction below, given the following reactions and subsequent \(\Delta \mathrm{H}\) values:
\[
\begin{array}{ll}
\mathrm{Zn}(\mathrm{~s})+1 / 8 \mathrm{~S}_{8}(\mathrm{~s})+2 \mathrm{O}_{2}(\mathrm{~g}) \rightarrow \mathrm{ZnSO}_{4}(\mathrm{~s}) \\
\mathrm{Zn}(\mathrm{~s})+1 / 8 \mathrm{~S}_{8}(\mathrm{~s}) \rightarrow 2 \mathrm{ZnS}(\mathrm{~s}) & \Delta \mathrm{H}=-183.92 \mathrm{~kJ} \\
2 \mathrm{ZnS}(\mathrm{~s})+3 \mathrm{O}_{2}(\mathrm{~g}) \rightarrow 2 \mathrm{ZnO}(\mathrm{~s})+2 \mathrm{SO}_{2}(\mathrm{~g}) & \Delta \mathrm{H}=-927.54 \mathrm{~kJ} \\
2 \mathrm{SO}_{2}(\mathrm{~g})+\mathrm{O}_{2}(\mathrm{~g}) \rightarrow 2 \mathrm{SO}_{3}(\mathrm{~g}) & \Delta \mathrm{H}=-196.04 \mathrm{~kJ} \\
\mathrm{ZnO}(\mathrm{~s})+\mathrm{SO}_{3}(\mathrm{~g}) \rightarrow \mathrm{ZnSO}_{4}(\mathrm{~s}) & \Delta \mathrm{H}=-230.32 \mathrm{~kJ}
\end{array}
\]```

