5.2 La loi de Hess

1. a)

$H_2SO_{4(l)} \rightarrow H_{2(g)} + S_{(s)} + 2\,O_{2(g)}$ $\quad \Delta H = +811{,}3$ kJ

$H_{2(g)} + \frac{1}{2}\,O_{2(g)} \rightarrow H_2O_{(g)}$ $\quad \Delta H = -241{,}8$ kJ

$S_{(s)} + O_{2(g)} \rightarrow SO_{2(g)}$ $\quad \Delta H = -296{,}1$ kJ

$H_2SO_{4(l)} \rightarrow \cancel{H_{2(g)}} + \cancel{S_{(s)}} + 2\,O_{2(g)}$

$\cancel{H_{2(g)}} + \frac{1}{2}\,O_{2(g)} \rightarrow H_2O_{(g)}$

$\cancel{S_{(s)}} + O_{2(g)} \rightarrow SO_{2(g)}$

$H_2SO_{4(l)} \rightarrow \frac{1}{2}\,O_{2(g)} + H_2O_{(g)} + SO_{2(g)}$ $\quad \Delta H = +273{,}4$ kJ

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b)

$N_2O_{(g)} \rightarrow N_{2(g)} + \frac{1}{2}\,O_{2(g)} + 81{,}6$ kJ

$N_{2(g)} + 2\,O_{2(g)} + 67{,}8$ kJ $\rightarrow 2\,NO_{2(g)}$

$N_2O_{(g)} \rightarrow \cancel{N_{2(g)}} + \frac{1}{2}\,O_{2(g)}$ $\quad \Delta H = -81{,}6$ kJ

$\cancel{N_{2(g)}} + 2\,O_{2(g)} \rightarrow 2\,NO_{2(g)}$ $\quad \Delta H = +67{,}8$ kJ

$N_2O_{(g)} + \frac{3}{2}\,O_{2(g)} \rightarrow 2\,NO_{2(g)}$ $\quad \Delta H = -13{,}8$ kJ

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c)

$H_2S_{(g)} \rightarrow H_{2(g)} + S_{(s)}$ $\quad \Delta H = +20{,}2$ kJ

$H_{2(g)} + \frac{1}{2}\,O_{2(g)} \rightarrow H_2O_{(g)}$ $\quad \Delta H = -241{,}8$ kJ

$S_{(s)} + O_{2(g)} \rightarrow SO_{2(g)}$ $\quad \Delta H = -296{,}1$ kJ

$H_2S_{(g)} \rightarrow \cancel{H_{2(g)}} + \cancel{S_{(s)}}$

$\cancel{H_{2(g)}} + \frac{1}{2}\,O_{2(g)} \rightarrow H_2O_{(g)}$

$\cancel{S_{(s)}} + O_{2(g)} \rightarrow SO_{2(g)}$

$H_2S_{(g)} + \frac{3}{2}\,O_{2(g)} \rightarrow H_2O_{(g)} + SO_{2(g)}$ $\quad \Delta H = -517{,}7$ kJ

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d)

$2\,C_{12}H_{22}O_{11(s)} \rightarrow \cancel{24\,C_{(s)}} + 22\,H_{2(g)} + \cancel{11\,O_{2(g)}}$ $\quad \Delta H = +4443{,}4$ kJ

$\cancel{24\,C_{(s)}} + 24\,O_{2(g)} \rightarrow 24\,CO_{2(g)}$ $\quad \Delta H = -9444$ kJ

$\cancel{22\,H_{2(g)}} + \cancel{11\,O_{2(g)}} \rightarrow 22\,H_2O_{(g)}$ $\quad \Delta H = -5319{,}6$ kJ

$2\,C_{12}H_{22}O_{11(s)} + 24\,O_{2(g)} \rightarrow 24\,CO_{2(g)} + 22\,H_2O_{(g)}$ $\quad \Delta H = -10\,320{,}2$ kJ

2.

$4\,NH_{3(g)} \rightarrow \cancel{2\,N_{2(g)}} + \cancel{6\,H_{2(g)}}$ $\quad \Delta H = +92{,}6$ kJ $\times 2 = +185{,}2$ kJ

$\cancel{2\,N_{2(g)}} + 4\,O_{2(g)} \rightarrow 4\,NO_{2(g)}$ $\quad \Delta H = +67{,}8$ kJ $\times 2 = +135{,}6$ kJ

$\cancel{6\,H_{2(g)}} + 3\,O_{2(g)} \rightarrow 6\,H_2O_{(g)}$ $\quad \Delta H = -241{,}8$ kJ $\times 6 = -1450{,}8$ kJ

$4\,NH_{3(g)} + 7\,O_{2(g)} \rightarrow 4\,NO_{2(g)} + 6\,H_2O_{(g)}$ $\quad \Delta H = -1130{,}0$ kJ

La loi de Hess (*suite*)

3.

$H_2SO_{4(l)} \rightarrow \cancel{H_{2(g)}} + \cancel{S_{(s)}} + 2\,O_{2(g)}$ $\quad \Delta H = +814\ kJ$

$\cancel{S_{(s)}} + O_{2(g)} \rightarrow SO_{2(g)}$ $\quad \Delta H = -297\ kJ$

$\cancel{H_{2(g)}} + \frac{1}{2}\,O_{2(g)} \rightarrow H_2O_{(g)}$ $\quad \Delta H = -242\ kJ$

$H_2SO_{4(g)} \rightarrow SO_{2(g)} + H_2O_{(g)} + \frac{1}{2}\,O_{2(g)}$ $\quad \Delta H = +275\ kJ$

4.

$2\,NO_{(g)} \rightarrow \cancel{N_{2(g)}} + O_{2(g)}$ $\quad \Delta H = (-90{,}3\ kJ \times 2) = -180{,}6\ kJ$

$\cancel{N_{2(g)}} + \frac{5}{2}\,O_{2(g)} \rightarrow N_2O_{5(g)}$ $\quad \Delta H = +11{,}3\ kJ$

$2\,NO_{(g)} + \frac{3}{2}\,O_{2(g)} \rightarrow N_2O_{5(g)}$ $\quad \Delta H = -169{,}3\ kJ$

$\frac{-169{,}3\ kJ}{2\ mol} = \frac{?\ kJ}{1\ mol}$

$\frac{-169{,}3\ kJ \times 1\ mol}{2\ mol} = -84{,}65\ kJ$

La chaleur molaire de la réaction du monoxyde d'azote est de –84,7 kJ/mol.

5.

L'équation globale

$C_{(s)} + 2\,S_{(s)} \rightarrow CS_{2(g)}$

$C_{(s)} + \cancel{O_{2(g)}} \rightarrow \cancel{CO_{2(g)}}$ $\quad \Delta H = -393{,}5\ kJ$

$2\,S_{(s)} + \cancel{2\,O_{2(g)}} \rightarrow \cancel{2\,SO_{2(g)}}$ $\quad \Delta H = 2 \times -296{,}8\ kJ = -593{,}6\ kJ$

$\cancel{CO_{2(g)}} + \cancel{2\,SO_{2(g)}} \rightarrow CS_{2(g)} + \cancel{3\,O_{2(g)}}$ $\quad \Delta H = +1072\ kJ$

$C_{(s)} + 2\,S_{(s)} \rightarrow CS_{2(g)}$ $\quad \Delta H = +84{,}9\ kJ$

6. **a)** $\frac{1}{2}\,N_{2(g)} + \frac{3}{2}\,F_{2(g)} \rightarrow NF_{3(g)}$ $\quad \Delta H = -124{,}7\ kJ$

b) $\frac{1}{2}\,H_{2(g)} + C_{(s)} + \frac{1}{2}\,N_{2(g)} \rightarrow HCN_{(g)}$ $\quad \Delta H = +135\ kJ$

c) $2\,Al_{(s)} + \frac{3}{2}\,O_{2(g)} \rightarrow Al_2O_{3(s)}$ $\quad \Delta H = -1676\ kJ$

d) $Mg_{(s)} + S_{(s)} + 2\,O_{2(g)} \rightarrow MgSO_{4(s)}$ $\quad \Delta H = -1285\ kJ$

La loi de Hess (*suite*)

7. a)

$$NO_{(g)} \rightarrow \cancel{\frac{1}{2} N_{2(g)}} + \frac{1}{2} O_{2(g)} \qquad \Delta H = -90{,}3\ kJ$$
$$\cancel{\frac{1}{2} N_{2(g)}} + O_{2(g)} \rightarrow NO_{2(g)} \qquad \Delta H = +33{,}2\ kJ$$
$$NO_{(g)} + \frac{1}{2} O_{2(g)} \rightarrow NO_{2(g)} \qquad \Delta H = -57{,}1\ kJ$$

b)

$$2\ CO_{(g)} \rightarrow \cancel{2\ C_{(s)}} + O_{2(g)} \qquad \Delta H = +110{,}5\ kJ \times 2 = +221\ kJ$$
$$\cancel{2\ C_{(s)}} + 2\ O_{2(g)} \rightarrow 2\ CO_{2(g)} \qquad \Delta H = -393{,}5\ kJ \times 2 = -787\ kJ$$
$$2\ CO_{(g)} + O_{2(g)} \rightarrow 2\ CO_{2(g)} \qquad \Delta H = -566\ kJ$$

c)

L'équation globale

$$H_2O_{(l)} \rightarrow H_2O_{(g)}$$

$$H_2O_{(l)} \rightarrow \cancel{H_{2(g)}} + \cancel{\frac{1}{2} O_{2(g)}} \qquad \Delta H = +285{,}8\ kJ$$
$$\cancel{H_{2(g)}} + \cancel{\frac{1}{2} O_{2(g)}} \rightarrow H_2O_{(g)} \qquad \Delta H = -241{,}8\ kJ$$
$$H_2O_{(l)} \rightarrow H_2O_{(g)} \qquad \Delta H = +44{,}0\ kJ$$

8.

L'équation globale

$$2\ C_2H_{2(g)} + 5\ O_{2(g)} \rightarrow 4\ CO_{2(g)} + 2\ H_2O_{(g)}$$

$$2\ C_2H_{2(g)} \rightarrow \cancel{4\ C_{(s)}} + \cancel{2\ H_{2(g)}} \qquad \Delta H = -226{,}7\ kJ \times 2 = -453{,}4\ kJ$$
$$\cancel{4\ C_{(s)}} + 4\ O_{2(g)} \rightarrow 4\ CO_{2(g)} \qquad \Delta H = -393{,}5\ kJ \times 4 = -1574\ kJ$$
$$\cancel{2\ H_{2(g)}} + O_{2(g)} \rightarrow 2\ H_2O_{(g)} \qquad \Delta H = -241{,}8\ kJ \times 2 = -483{,}6\ kJ$$
$$2\ C_2H_{2(g)} + 5\ O_{2(g)} \rightarrow 4\ CO_{2(g)} + 2\ H_2O_{(g)} \qquad \Delta H = -2511\ kJ$$

Calcul de la chaleur molaire

$$\frac{-2511\ kJ}{2\ mol} = -1255{,}5\ kJ/mol$$

La chaleur molaire de combustion de l'acétylène est de −1256 kJ/mol.

La loi de Hess (*suite*)

9.

L'équation globale

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

$C_3H_{8(g)} \rightarrow \cancel{3\,C_{(s)}} + \cancel{4\,H_{2(g)}}$	$\Delta H = +103{,}8\ kJ$
$\cancel{3\,C_{(s)}} + 3\,O_{2(g)} \rightarrow 3\,CO_{2(g)}$	$\Delta H = -393{,}5\ kJ \times 3 = -1180{,}5\ kJ$
$\cancel{4\,H_{2(g)}} + 2\,O_{2(g)} \rightarrow 4\,H_2O_{(l)}$	$\Delta H = -285{,}8\ kJ \times 4 = -1143{,}2\ kJ$
$C_3H_{8(g)} + 5\,O_{2(g)} \rightarrow 3\,CO_{2(g)} + 4\,H_2O_{(g)}$	$\Delta H = -2\,219{,}9\ kJ$

10. a) *Ce mécanisme comporte quatre étapes.*

b) $H_r = 0\ kJ$

c) $H_p = -10\ kJ$

d) $\Delta H = H_p - H_r$
$= -10\ kJ - 0\ kJ = -10\ kJ$

e) $E_a = H_{ca} - H_r$
$= 20\ kJ - 0\ kJ = 20\ kJ$

f) $H_{ca} = 60\ kJ$

g) $E_a = H_{ca} - H_r$
$= 60\ kJ - 10\ kJ = 50\ kJ$

h) $\Delta H = H_p - H_r$
$= 10\ kJ - 0\ kJ = 10\ kJ$

i) $\Delta H = H_p - H_r$
$= 40\ kJ - 10\ kJ = +30\ kJ$

11. *c)*