Hess's Law and Standard Enthalpy of Formation Practice Questions – Answers

1.
   (a) $Ca_{(s)} + O_{2\,(g)} + H_{2\,(g)} \rightarrow Ca(OH)_{2\,(s)}$ ΔH = - 981.6 kJ
   (b) $6\,C_{(s)} + 3\,H_{2\,(g)} \rightarrow C_6H_{6\,(l)}$ ΔH = + 49.0 kJ
   (c) $2\,Na_{(s)} + C_{(s)} + 3/2\,O_{2\,(g)} \rightarrow Na_2CO_{3\,(s)}$ ΔH =
   (d) $Ca_{(s)} + F_{2\,(g)} \rightarrow CaF_{2\,(s)}$ ΔH =
   (e) $\frac{1}{4}\,P_{4\,(s)} + 3/2\,H_{2\,(g)} \rightarrow PH_{3\,(g)}$ ΔH =
   (f) $3\,C_{(s)} + 4\,H_{2\,(g)} \rightarrow C_3H_{8\,(g)}$ ΔH =
   (g) $1/8\,S_{8\,(s)} \rightarrow S_{(g)}$ ΔH =

2. Target: $2\,HCl_{(g)} + F_{2\,(g)} \rightarrow 2HF_{(l)} + Cl_{2\,(g)}$.

$4\,\mathbf{HCl}_{(g)} + O_{2\,(g)}$	$\rightarrow$	$2\,H_2O_{(l)} + 2\,\mathbf{Cl_2}_{(g)}$	ΔH = - 202.4 kJ	x ½
$\frac{1}{2}\,H_{2\,(g)} + \frac{1}{2}\,\mathbf{F_2}_{(g)}$	$\rightarrow$	$\mathbf{HF}_{(l)}$	ΔH = - 600.0 kJ	x 2
$H_{2\,(g)} + \frac{1}{2}\,O_{2\,(g)}$	$\rightarrow$	$H_2O_{(l)}$	ΔH = - 285.8 kJ	x -1

$2\,HCl_{(g)} + \frac{1}{2}\,O_{2\,(g)}$	$\rightarrow$	$H_2O_{(l)} + Cl_{2\,(g)}$	½ ΔH = - 101.2 kJ
$H_{2\,(g)} + F_{2\,(g)}$	$\rightarrow$	$2\,HF_{(l)}$	ΔH = - 1200.0 kJ
$H_2O_{(l)}$	$\rightarrow$	$H_{2\,(g)} + \frac{1}{2}\,O_{2\,(g)}$	ΔH = 285.8 kJ

$2\,HCl_{(g)} + F_{2\,(g)} \rightarrow 2HF_{(l)} + Cl_{2\,(g)}$.

$\Delta H = \frac{1}{2}\,\Delta H_1 + 2\,\Delta H_2 + -\Delta H_3 = -1015.4$ kJ

3. $\Delta H = -\Delta H_1 + -\Delta H_2 + -\Delta H_3$ ΔH = -96.6 kJ
4. $\Delta H = \Delta H_1 - \Delta H_2$ ΔH = 98.8 kJ
5. $\Delta H = 1/3\,\Delta H_1 - 1/3\Delta H_2$ ΔH = -312 kJ

6. and
7.

Propane: $C_3H_{8\ (g)}$ + $5\ O_{2\ (g)}$ → $3\ CO_2$ + $4\ H_2O_{\ (g)}$

ΔH_f -104.7 0 -393.8 -241.8

$\Delta H = \sum n\Delta H_{f\ prod} - \sum n\Delta H_{f\ react}$

= [(3 mol CO_2)(-393.8 kJ/mol CO_2) + (4 molH_2O)(-241.8 kJ/mol H_2O)] –
[(1 mol C_3H_8)(-104.7 kJ/mol C_3H_8) + (5 mol O_2)(0 kJ/mol O_2)]

= -2043 kJ

ΔH_{rxn} = ΔH/n frpm balanced equation n = 1 mol C_3H_8

ΔH_{rxn} = -2043 kJ/mol C_3H_8

ΔH_{rxn} = -2043 kJ/mol C_3H_8 ÷ (44.11 g C_3H_8/mol C_3H_8) = - 46.32 kJ/g C_3H_8

Propane: ΔH_{rxn} = -46.32 kJ/g C_3H_8

Octane: $C_8H_{18\ (l)}$ + $25/2\ O_{2\ (g)}$ → $8\ CO_2$ + $9\ H_2O_{\ (g)}$

ΔH_f --250.1 0 -393.8 -241.8

$\Delta H = \sum n\Delta H_{f\ prod} - \sum n\Delta H_{f\ react}$

= [(8 mol CO_2)(-393.8 kJ/mol CO_2) + (9 molH_2O)(-241.8 kJ/mol H_2O)] –
[(1 mol C_8H_{18})(-250.1 kJ/mol C_8H_{18}) + (25/2 mol O_2)(0 kJ/mol O_2)]

= -5074 kJ

ΔH_{rxn} = ΔH/n frpm balanced equation n = 1 mol C_8H_{18}

ΔH_{rxn} = -5074 kJ/mol C_8H_{18}

ΔH_{rxn} = -5074 kJ/mol C_8H_{18} ÷ (114.24 g C_3H_8/mol C_8H_{18}) = - 44.42 kJ/g C_8H_{18}

Octane: ΔH_{rxn} = -44.42 kJ/g C_8H_{18}

Methane: $CH_{4\ (g)}$ + $O_{2\ (g)}$ → CO_2 + $2\ H_2O_{\ (g)}$

ΔH_f -74.4 0 -393.8 -241.8

$\Delta H = \sum n\Delta H_{f\ prod} - \sum n\Delta H_{f\ react}$

= [(1 mol CO_2)(-393.8 kJ/mol CO_2) + (2 mol H_2O)(-241.8 kJ/mol H_2O)] –
[(1 mol CH_4)(-74.4 kJ/mol CH_4) + (1 mol O_2)(0 kJ/mol O_2)]

= -802.7 kJ

ΔH_{rxn} = ΔH/n frpm balanced equation n = 1 mol CH_4

ΔH_{rxn} = -802.7 kJ/mol CH_4

ΔH_{rxn} = -802.7 kJ/mol C_3H_8 ÷ (16.05 g CH_4/mol CH_4) = - 50.01 kJ/g CH_4

Propane: ΔH_{rxn} = -50.01 kJ/g CH_4

8. $8\ Al_{(s)}$ + $3\ Fe_3O_{4\ (s)}$ → $4\ Al_2O_{3\ (s)}$ + $9\ Fe_{(s)}$

23 g   57.6 g

26.98 g/mol   231.55 g/mol

let Al be limiting:

m Fe_3O_4 = m Al / M Al x mol ratio x M Fe_3O_4

= (23 g Al) / (26.98 g/mol) x (3 mol Fe_3O_4 / 8 mol Al) x (231.55 g Fe_3O_4 / mol Fe_3O_4)

= 74.02 g

m Fe_3O_4 req'd > m Fe_3O_4 have, therefore Fe_3O_4 is limiting

ΔH_{rxn} = ΔH / n = - 3350 kJ / 3 mol Fe_3O_4 = - 111.7 kJ / mol Fe_3O_4

ΔH = $n\Delta H_{rxn}$ = (57.6 g Fe_3O_4) / (231.55 g Fe_3O_4 / mol Fe_3O_4) x (-1111.7 kJ / mol Fe_3O_4)

= -272.2 kJ

	$8\ Al_{(s)}$	+	$3\ Fe_3O_{4\ (s)}$	→	$4\ Al_2O_{3\ (s)}$	+	$9\ Fe_{(s)}$
ΔH_f	0		x		-1675.7		0

ΔH = $\sum n\Delta H_{f\ prod} - \sum n\Delta H_{f\ react}$

-3350 kJ = [(4 mol Al_2O_3)(-1675.7 kJ/mol Al_2O_3) + (9 mol Fe)(0 kJ/mol Fe)] –

[(8 mol Al)(0 kJ/mol Al) + (3 mol Fe_3O_4)(x kJ/mol Fe_3O_4)]

x = - 1117.6 kJ/mol Fe_3O_4

9. ΔH = 1.55×10^5 kJ ΔH_f = 226.7 kJ/mol C_2H_2

10. ΔH_f = -64.6 kJ/mol SiC