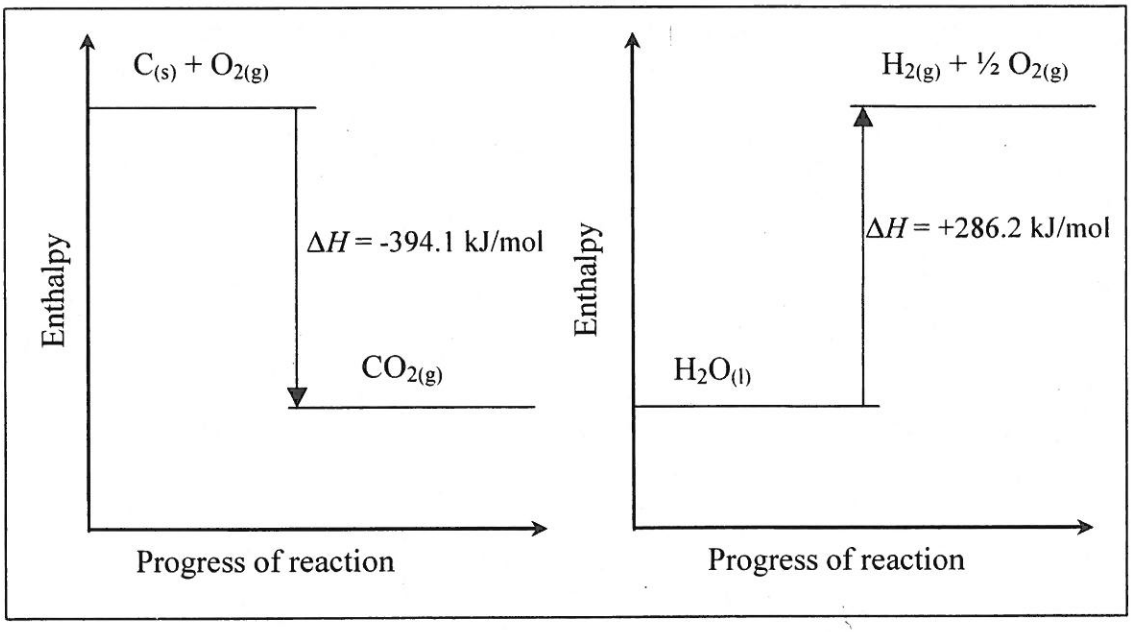
ANS key.

1. Glucose, $C_6H_{12}O_6$, is the fundamental energy source for humans.

$$C_6H_{12}O_{6(s)} + 6O_{2(g)} \rightarrow 6\,CO_{2(g)} + 6\,H_2O_{(l)}$$

Determine the amount of heat produced by the combustion of 90.0 g of glucose using the information below.

$$6\,C_{(s)} + 6\,H_{2(g)} + 3\,O_{2(g)} \rightarrow C_6H_{12}O_{6(s)} \quad \Delta H = -1274.5\ kJ/mol$$




BIM : Réponse

**SHOW ALL YOUR WORK**

$6C + 6H_2 + 3O_2 \rightarrow C_6H_{12}O_6$ $\quad \Delta H = -1274.5\ KJ/mol$ rev.

$C + O_2 \rightarrow CO_2$ $\quad \Delta H = -394.1\ KJ/mol$ ×6

$H_2O \rightarrow H_2 + \frac{1}{2}O_2$ $\quad \Delta H = 286.2\ KJ/mol$ rev ×6

$C_6H_{12}O_6 \rightarrow 6C + 6H_2 + 3O_2$

$6C + 6O_2 \rightarrow 6CO_2$

$+\ 6H_2 + 3O_2 \rightarrow 6H_2O$

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$

1274.5
−2364.0
+−1717.2

$n = \frac{m}{m}$ $\quad n = \frac{90.\text{g}}{180.18\ \text{g/mol}}$

$n = 0.4995$ mol

$\Delta H = \frac{-2806.7\text{kJ}}{0.4995\text{mol}}$

(Include units of measurement.)

Answer: The amount of heat produced is $-5,619.0\ KJ/mol$.

2. When phosphorus is burned in an excess of oxygen, tetraphosphorus decoxide, $P_4O_{10}$, is formed as shown:

$$4\ P_{(s)} + 5\ O_{2(g)} \rightarrow P_4O_{10(s)} \qquad \Delta H_f = ?$$

Use the equations below to calculate the $\Delta H$ of formation of tetra phosphorus decoxide.

| | |
|---|---|
| $2\ PCl_{3(l)} + O_{2(g)} \rightarrow 2\ POCl_{3(l)}$ | $\Delta H = -587$ kJ $\times 5$ |
| $P_4O_{10(s)} + 6\ PCl_{5(s)} \rightarrow 10\ POCl_{3(l)}$ | $\Delta H = -419$ kJ rev |
| $2\ P_{(s)} + 3\ Cl_{2(g)} \rightarrow 2\ PCl_{3(l)}$ | $\Delta H = -686$ kJ $\times 5$ |
| $2\ P_{(s)} + 5\ Cl_{2(g)} \rightarrow 2\ PCl_{5(s)}$ | $\Delta H = -892$ kJ rev $\times 3$ |

$10\ PCl_3 + 5O_2 \rightarrow 10\ POCl_3$ $\quad -2935$

$10\ POCl_3 \rightarrow 6\ PCl_5 + P_4O_{10}$ $\quad 419$

$10\ P + 15\ Cl_2 \rightarrow 10\ PCl_3$ $\quad -3430$

$6\ PCl_5 \rightarrow 6\ P + 15\ Cl_2$ $\quad +2676$

$-3270$ KJ/mol

$4P + 5O_2 \rightarrow P_4O_{10}$

5. During two experiments, students determine the heats of reaction for the following thermochemical equations:

$NaOH_{(s)} \rightarrow NaOH_{(aq)} + 44.2\ kJ$ flip $\Delta H = -44.2$

$NaOH_{(s)} + HCl_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)} + 100.1\ kJ$ $\Delta H = -100.1$

$NaOH_{(aq)} \rightarrow NaOH_{(s)}$ $\Delta H = 44.2$

In a third experiment, 150.0 mL of aqueous sodium hydroxide, $NaOH_{(aq)}$, is mixed with 150.0 mL of hydrochloric acid, $HCl_{(aq)}$ and the temperature of the solution rises from 25.0°C to 38.0°C.

This reaction is represented by the following equation:

$$NaOH_{(aq)} + HCl_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$$

How many moles of NaOH reacted in the third experiment?
**(Assume $NaOH_{(aq)}$ and $HCl_{(aq)}$ have the same specific heat capacity and density as water.)**

$NaOH_{(aq)} + HCl \rightarrow NaCl + H_2O \quad \Delta H = -55.9\ KJ/mol$

$Q = mc\Delta T$

$Q = 150g \times 4.19\ J/g°C \times 13°C$

$Q = 16341\ J \times \frac{1\ KJ}{1000\ J}$

$\Delta H = \frac{-Q}{n}$

$-55.9\ KJ/mol = \frac{16.341\ KJ}{n}$

$n = 0.292\ mol$

pg 208 #2

-14.8 KJ/mol ?-34.75 KJ/mol

#3 -851.5 KJ

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#7 226.8 KJ/mol

#8 B

#9 -2043 KJ

**Solutions**

Reactions that were reversed or multiplied by a constant are shown in italics.

1. **$\Delta H = -137.$ kJ**

$C_2H_4\ (g) + 3\ O_2\ (g) \rightarrow 2\ CO_2\ (g) + 2\ H_2O\ (l)$ $\quad \Delta H = -1411.$ kJ

*$2\ CO_2\ (g) + 3\ H_2O\ (l) \rightarrow C_2H_6\ (g) + 7/2\ O_2\ (g)$* $\quad \Delta H = +1560.$ kJ

$H_2\ (g) + 1/2\ O_2\ (g) \rightarrow H_2O\ (l)$ $\quad \Delta H = -285.8$ kJ

2. **$\Delta H = -1628.$ kJ**

*$2\ N_2\ (g) + 2\ O_2\ (g) \rightarrow 4\ NO\ (g)$* $\quad \Delta H = 2 \times (-180.5$ kJ)

*$4\ NH_3\ (g) \rightarrow 2\ N_2\ (g) + 6\ H_2\ (g)$* $\quad \Delta H = 2 \times (+91.8$ kJ)

*$6\ H_2\ (g) + 3\ O_2\ (g) \rightarrow 6\ H_2O\ (g)$* $\quad \Delta H = 3 \times (-483.6$ kJ)

3. **$\Delta H_f^0 = -486.$ kJ**

Reaction defining $\Delta H_f^0\ (HC_2H_3O_2)$ is: $2\ C(s, \text{graphite}) + 2\ H_2\ (g) + O_2\ (g) \rightarrow HC_2H_3O_2\ (l)$.

*$2\ CO_2\ (g) + 2\ H_2O\ (l) \rightarrow HC_2H_3O_2\ (l) + 2\ O_2\ (g)$* $\quad \Delta H = +875.$ kJ

*$2\ C\ (s, \text{graphite}) + 2\ O_2\ (g) \rightarrow 2\ CO_2\ (g)$* $\quad \Delta H = 2 \times (-394.51$ kJ)

*$2\ H_2\ (g) + O_2\ (g) \rightarrow 2\ H_2O\ (l)$* $\quad \Delta H = 2 \times (-285.8$ kJ)

4. **$\Delta H = +256.0$ kJ**

*$NH_3\ (g) \rightarrow 1/2\ N_2\ (g) + 3/2\ H_2\ (g)$* $\quad \Delta H = 1/2 \times (+91.8$ kJ)

*$CH_4\ (g) \rightarrow C\ (s, \text{graphite}) + 2\ H_2\ (g)$* $\quad \Delta H = +74.9$ kJ

$1/2\ H_2\ (g) + C\ (s, \text{graphite}) + 1/2\ N_2\ (g) \rightarrow HCN\ (g)$ $\quad \Delta H = 1/2 \times (+270.3$ kJ)

5. **$\Delta H = -6387.$ kJ**

$2\ Al\ (s) + 6\ HCl\ (aq) \rightarrow 2\ AlCl_3\ (aq) + 3\ H_2\ (g)$ $\quad \Delta H = -1049.$ kJ

*$6\ HCl\ (g) \rightarrow 6\ HCl\ (aq)$* $\quad \Delta H = 6 \times (-74.8$ kJ)

*$3\ H_2\ (g) + 3\ Cl_2\ (g) \rightarrow 6\ HCl\ (g)$* $\quad \Delta H = 3 \times (-1845.$ kJ)

*$2\ AlCl_3\ (aq) \rightarrow 2\ AlCl_3\ (s)$* $\quad \Delta H = 2 \times (+323.$ kJ)

## Experiment 1

$$Q = mc\Delta T$$

$$Q = 1000\,g\left(4.19\,\frac{J}{g^{\circ}C}\right)(10.3\,^{\circ}C)$$

$$Q_w = 43{,}157\,J$$

$$4\,g\,Ca \times \frac{1\,mol\,Ca}{40.08\,g\,Ca} = 0.09980\,mol\,Ca$$

$$\Delta H = -\frac{Q}{n}$$

$$\Delta H = -\frac{43.157\,kJ}{0.09980\,mol\,Ca} = -440.24\,kJ/mol\,Ca \times \frac{1\,mol\,Ca}{}$$

$$= -440.24\,kJ$$

$$= -440.24\,kJ/mol$$

## Experiment 2

$$Q = mc\Delta T$$

$$Q = 1000\,g \times \left(4.19\,\frac{J}{g^{\circ}C}\right)(1.9\,^{\circ}C)$$

$$Q = 7{,}961\,J$$

$$5.6\,g\,CaO \times \frac{1\,mol\,CaO}{56.08\,g\,CaO} = 0.09986\,mol\,CaO$$

$$\Delta H = -\frac{Q}{n}$$

$$\Delta H = -\frac{7.961\,kJ}{0.09986\,mol\,CaO}$$

$$\Delta H = -79.72\,kJ/mol\,CaO$$

$$-79.72\,\frac{kJ}{mol}\,CaO \times \frac{1\,mol\,CaO}{}$$

$$= -79.72\,kJ$$

$Ca_{(s)} + 2H_2O_{(l)} \rightarrow Ca^{2+}_{(aq)} + 2OH^-_{(aq)} + H_{2(g)}$ $\Delta H = -432.43 \frac{kJ}{mol}$

↪ $CaO_{(s)} + H_2O_{(l)} \rightarrow Ca^{2+}_{(aq)} + 2OH^-_{(aq)}$ $\Delta H = -79.72 \frac{kJ}{mol}$

$H_{2(g)} + \frac{1}{2} O_{2(g)} \rightarrow H_2O_{(l)}$ $\Delta H = -286 \text{ kJ/mol}$

~~$Ca_{(s)} + 2H_2O_{(l)} \rightarrow Ca^{2+}_{(aq)} + 2OH^-_{(aq)} + H_{2(g)}$~~ $\Delta H = -432.43 \text{ kJ/mol}$

~~$Ca^{2+}_{(aq)} + 2OH^-_{(aq)} \rightarrow CaO_{(s)} + H_2O_{(l)}$~~ $\Delta H = 79.72 \frac{kJ}{mol}$

~~$H_{2(g)} + \frac{1}{2} O_{2(g)} \rightarrow H_2O_{(l)}$~~ $\Delta H = -286 \frac{kJ}{mol}$

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$Ca_{(s)} + \frac{1}{2} O_{2(g)} \rightarrow CaO_{(s)}$

$-646.52 \text{ kJ/mol}$

Che

Modul... Hess's Law

**Calculate the ΔH of the following reactions using Hess's Law and the steps indicated. Show all your work.**

1) Calculate the heat released by the burning of sulfur in oxygen given the following steps

$2S(s) + 3O_2(g) \rightarrow 2SO_3(g) \quad \Delta H = ?$ −792 kJ/mol

Given Steps

X2 $S(s) + O_2(g) \rightarrow SO_2(g) \quad \Delta H = -297$ kJ

$2SO_2(g) + O_2(g) \rightarrow 2SO_3(g) \quad \Delta H = -198$ kJ

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2) Calculate the ΔH of the following reaction, which describes the production of coal gas from carbon, given the steps below.

$H_2O(g) + C(s) \rightarrow CO(g) + H_2(g)$ −131.5 kJ/mol

Given Steps

$H_2(g) + 1/2\ O_2(g) \rightarrow H_2O(g) \quad \Delta H = -242.0$ kJ

÷2 $2CO(g) \rightarrow 2C(s) + O_2(g) \quad \Delta H = +221.0$ kJ

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3) Calculate the heat of reaction for the following equation

$C_3H_8(g) + 5\ O_2(g) \text{ -----> } 3\ CO_2(g) + 4\ H_2O(g)$ −2252.3 kJ/mol

given the following steps in the reaction mechanism.

X2 $3C(s) + 4\ H_2(g) \text{ -------> } C_3H_8(g) \quad \Delta H = 103.8$ KJ

X3 $2\ H_2(g) + O_2(g) \text{ -------> } 2H_2O(g) \quad \Delta H = -484$ KJ

$C(s) + O_2(g) \text{ --------> } CO_2(g) \quad \Delta H = -393.5$ KJ

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4. Determining ΔH for the reaction $C(s) + \frac{1}{2}O_2(g) \rightarrow CO(g)$ −110.5 kJ/mol

given the following steps in the reaction mechanism.

$C(s) + O_2(g) \rightarrow CO_2(g) \quad \Delta H = -393.5$ kJ

$-$ $CO(g) + \frac{1}{2}O_2(g) \rightarrow CO_2(g) \quad \Delta H = -283.0$ kJ

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Chem 584

Module 3: Hess's Law

5 Carbon occurs in two forms: graphite and diamond.

$C(\text{graphite}) + O_2(g) \rightarrow CO_2(g) \quad \Delta H = -393.5$ kJ

$C(\text{diamond}) + O_2(g) \rightarrow CO_2(g) \quad \Delta H = -395.4$ kJ

Calculate ΔH for the conversion of graphite to diamond 1.9 kJ/mol

What we want is ΔH for the reaction: C(graphite) -> C(diamond)

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6. Overall reaction

$2CO(g) + O_2(g) \rightarrow 2CO_2(g) \quad \Delta H = ?$ −566 kJ/mol

Steps

$C(s) + O_2(g) \rightarrow CO_2(g) \quad \Delta H = -393.5$ kJ

×2 $C(s) + 1/2\ O_2(g) \rightarrow CO(g) \quad \Delta H = -110.5$ kJ.

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7. Overall reaction

$2\ Fe(s) + 3CO_2(g) \rightarrow 3CO(g) + Fe_2O_3(s) \quad \Delta H = ?$

Steps

$4\ Fe(s) + 3\ O_2(g) \rightarrow 2Fe_2O_3(s) \quad \Delta H = -1644$ kJ

$CO(s) + 1/2\ O_2(g) \rightarrow CO_2(g) \quad \Delta H = -283$ kJ

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8. Overall reaction

$NH_4Cl(s) \rightarrow NH_3(g) + HCl(g) \quad \Delta H = ?$ 171.5 kJ/mol

Steps

÷2 $N_2(g) + 3\ H_2(g) \rightarrow 2\ NH_3(g) \quad \Delta H = -91.2$ kJ

÷2 $H_2(g) + Cl_2(g) \rightarrow 2\ HCl(g) \quad \Delta H = -184.6$ kJ

÷2 $N_2(g) + 4\ H_2(g) + Cl_2(g) \rightarrow 2\ NH_4Cl(s) \quad \Delta H = -618.8$ kJ

References: http://www.saskschools.ca/curr_content/chem30/modules/module3/lesson4/lesson4.html

http://wine1.sb.fsu.edu/chm1045/notes/Energy/HessLaw/Energy04.htm