Answer key

10/08/25

Calculating Enthalpy

What are the steps for calculating Hess' Law?

1) If rxn is reversed, sign ΔH is reversed

2) Make coefficients the same for the same element.
   ↳ Multiply ΔH value by integar amount for coefficients

keep $C(graphite) + O_2(g) \longrightarrow CO_2(g)$ $\Delta H = -393.5kJ$

flip $C(diamond) + O_2(g) \longrightarrow CO_2(g)$ $\Delta H = -395.4kJ$

Calculate ΔH for the conversion of graphite to diamond:

$C(graphite) \longrightarrow C(diamond)$ $\Delta H = ?$

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

$CO_2(g) \rightarrow C(diamond) + O_2(g)$ $\Delta H = +395.4\ kJ$

$C(graphite) \rightarrow C(diamond)$ $\Delta H = 1.9\ kJ$

Calculate ΔH for the reaction

$2C(s) + H_2(g) \longrightarrow C_2H_2(g)$

given the following chemical equations:

flip $C_2H_2(g) + 5/2\ O_2(g) \longrightarrow 2CO_2(g) + H_2O(l)$ $\Delta H = -1299.6kJ$

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

keep $H_2(g) + ½\ O_2(g) \longrightarrow H_2O(l)$ $\Delta H = -285.8kJ$

$2CO_2(g) + H_2O(l) \rightarrow C_2H_2(g) + 5/2\ O_2(g)$ $\Delta H = +1299.6\ kJ$

$2C(s) + 2O_2(g) \rightarrow 2CO_2(g)$ $\Delta H = -787.0\ kJ$

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

$2C(s) + 2O_2(g) + H_2(g) + 1/2\ O_2(g) \rightarrow C_2H_2(g) + 5/2\ O_2(g)$

$2.5\ O_2$ $2.5\ O_2$

$2C(s) + H_2(g) \rightarrow C_2H_2(g)$ $\Delta H = 226.8\ kJ$

How is enthalpy of formation depicted as a sign (its abbreviation)?

ΔH_f°

Standard enthalpies of formation are measured under what conditions?

Measured under conditions of 25°C + 1.00 atm pressure

- Gases = pressure = 1 atm
- Substance in solution = 1 M concentration
- Standard state is the pure liquid or solid
- Any element exists as $\Delta H_f^\circ = 0$

Is either of the following chemical equations a standard enthalpy formation?

$2Na\ (s) + \frac{1}{2}\ O_2\ (g) \longrightarrow Na_2O\ (s)$ standard enthalpy formation

↑ In solid elemental form

$2K\ (l) + Cl_2\ (g) \longrightarrow 2KCl\ (s)$ Not in standard enthalpy formation

↑ Not in most stable elemental form
- Supposed to be a solid

What is the equation for standard enthalpy of formation?

$\Delta H^\circ_{reaction} = \sum_n \Delta H_f^\circ\ products - \sum n \Delta Hf^\circ\ reactants$

products − reactants

$\sum$ = sum of ΔHf° = standard enthalpy of formation

TABLE 5.3 ■ Standard Enthalpies of Formation, ΔH_f°, at 298 K

Substance	Formula	ΔH_f (kJ mol)	Substance	Formula	ΔH_f (kJ mol)
Acetylene	$C_2H_2(g)$	226.7	Hydrogen chloride	$HCl(g)$	−92.30
Ammonia	$NH_3(g)$	−46.19	Hydrogen fluoride	$HF(g)$	−268.60
Benzene	$C_6H_6(l)$	49.0	Hydrogen iodide	$HI(g)$	25.9
Calcium carbonate	$CaCO_3(s)$	−1207.1	Methane	$CH_4(g)$	−74.80
Calcium oxide	$CaO(s)$	−635.5	Methanol	$CH_3OH(l)$	−238.6
Carbon dioxide	$CO_2(g)$	−393.5	Propane	$C_3H_8(g)$	−103.85
Carbon monoxide	$CO(g)$	−110.5	Silver chloride	$AgCl(s)$	−127.0
Diamond	$C(s)$	1.88	Sodium bicarbonate	$NaHCO_3(s)$	−947.7
Ethane	$C_2H_6(g)$	−84.68	Sodium carbonate	$Na_2CO_3(s)$	−1130.9
Ethanol	$C_2H_5OH(l)$	−277.7	Sodium chloride	$NaCl(s)$	−410.9
Ethylene	$C_2H_4(g)$	52.30	Sucrose	$C_{12}H_{22}O_{11}(s)$	−2221
Glucose	$C_6H_{12}O_6(s)$	−1273	Water	$H_2O(l)$	−285.8
Hydrogen bromide	$HBr(g)$	−36.23	Water vapor	$H_2O(g)$	−241.8

Calculate the enthalpy for the following reaction using the table above:

products − reactants

$$C_3H_8\,(g) + 5\,O_2\,(g) \longrightarrow 3\,CO_2\,(g) + 4\,H_2O\,(l)$$

$$\left[\left(3\text{X} - 393.5\ \text{kJ/mol}\right)_{CO_2} + \left(4\text{X} - 285.8\ \text{kJ/mol}\right)_{H_2O}\right] - \left[\left(1\text{X} - 103.55\ \text{kJ/mol}\right)_{C_3H_8} + \left(0\right)_{O_2}\right]$$

$$-2323.7 \qquad - \qquad 103.85$$

$$= \boxed{-2427.6\ \text{kJ}}$$

Calculate the enthalpy for the following reaction using the table above:

products − reactants

$$CH_4\,(g) + 2\,O_2\,(g) \longrightarrow CO_2\,(g) + 2H_2O\,(l)$$

$$\left[\left(1\text{X} - 393.5\text{kJ}\right)_{CO_2} + \left(2\text{X} - 285.8\text{kJ}\right)_{H_2O}\right] - \left[\left(1\text{X} \quad \text{kJ}\right)_{CH_4} + \left(2\text{X}\ 0\ \text{kJ}\right)_{O_2}\right]$$

$$-965.1 \qquad - \qquad -74.8$$

$$\Delta H^\circ_{rxn} = \boxed{-890.3\ \text{kJ}}$$

What is bond enthalpy?

Enthalpy associated with breaking 1 mole of a certain bond in a gaseous substance

Are bonds breaking endothermic or exothermic? Are bonds forming endothermic or exothermic?

Bond breaking = endothermic
- Requires energy

Bonds forming = exothermic
- Releases energy

What is the equation for bond enthalpy?

$\Delta H_{rxn} = \Sigma$(bond enthalpies of bonds broken) $- \Sigma$(bond enthalpies of bonds formed)

Reactants − Products

Average Bond Energies					
Bond	Bond Energy (kJ/mol)	Bond	Bond Energy (kJ/mol)	Bond	Bond Energy (kJ/mol)
H–H	436	C–C	347	O–O	142
H–C	414	C=C	611	O=O	498
H–N	389	C≡C	837	O–F	190
H–O	464	C–N	305	O–Cl	203
H–Cl	431	C=N	615	O–I	234
H–Br	364	C≡N	891	F–F	159
H–I	297	C–O	360	Cl–Cl	243
C–F	485	C=O	736*	F–F	159
C–Cl	339	C≡O	1072	Cl–F	253
C–Br	276				
C–I	240	*799 in CO_2			

What is the enthalpy for the following reaction using the table above?

$2\ H_2 + O_2 \longrightarrow 2\ H_2O$

Reactants − products

$[(2 \times 436\ kJ) + (1 \times 498\ kJ)] - [(4 \times 464\ kJ)]$

$1370\ kJ - 1856\ kJ$

$= -486\ kJ$

$2H_2$ = H : H or H–H

H–H

O_2 = :Ö::Ö: or O=O

$2H_2O$ = H : Ö : H or H–O–H

H–O–H