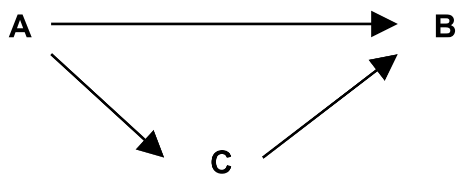
HESS'S LAW 1 - FORMATION

Hess's Law: The enthalpy change for a reaction is independent of the route taken



e.g. the enthalpy change to go from A → B direct is the same as going from A → C → B

- If the enthalpy of formation for the reactants and products in a reaction are known, the overall enthalpy change is easy to calculate.

ΔH = [SUM of $\Delta_f H$ products] – [SUM $\Delta_f H$ reactants]

- Some people refer to calculations done this way as "type 1 calculations".
- Remember that ΔH_f of all elements is zero.
- Watch for the very frequent mistake of doing *reactants – products*, rather than *products – reactants*.
- If the overall enthalpy change for a reaction is known along with the enthalpy of formation of all but one of the reactants/products, then this equation can be used to find the missing enthalpy of formation.

Example 1

Calculate the overall enthalpy change for this reaction: $CH_4(g) + 2\ O_2(g) \rightarrow CO_2(g) + 2\ H_2O(l)$

$\Delta_f H$ $CH_4(g)$ = –75, $CO_2(g)$ = –393, $H_2O(l)$ = –286 kJ/mol

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Example 2

The enthalpy change for the following reaction is –2877 kJ/mol: $C_4H_{10}(g) + 6\frac{1}{2}\ O_2(g) \rightarrow 4\ CO_2(g) + 5\ H_2O(l)$

Calculate the enthalpy change of formation of butane ($C_4H_{10}(g)$) given the following data:

$\Delta_f H$ $CO_2(g)$ = –393, $H_2O(l)$ = –286 kJ/mol

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1) Calculate the ΔH for the following reactions given the values of $\Delta_f H$ in the following table.

	$ZnCO_3(s)$	$ZnO(s)$	$CO_2(g)$	$CO(g)$	$H_2O(l)$	$Fe_2O_3(s)$	$Al_2O_3(s)$	$C_2H_4(g)$
$\Delta_f H$ (kJ/mol)	–812	–348	–393	–111	–286	–822	–1669	+52

a) $ZnCO_3(s) \rightarrow ZnO(s) + CO_2(g)$

b) $2\ CO(g) + O_2(g) \rightarrow 2\ CO_2(g)$

c) $2\ Al(s) + Fe_2O_3(s) \rightarrow 2\ Fe(s) + Al_2O_3(s)$

d) $C_2H_4(g) + 3\ O_2(g) \rightarrow 2\ CO_2(g) + 2\ H_2O(l)$

e) $C_2H_4(g) + 2\ O_2(g) \rightarrow 2\ CO(g) + 2\ H_2O(l)$

2) The ΔH for the following reaction is shown.

$$N_2H_4(l) + O_2(g) \rightarrow 2\ H_2O(l) + N_2(g) \qquad \Delta H = -623\ kJ\ mol^{-1}$$

Given that the $\Delta_f H$ of $H_2O(g)$ is –286 kJ mol^{-1}, calculate the $\Delta_f H$ of $N_2H_4(l)$.

3) Calculate the $\Delta_f H$ of ethane, $C_2H_6(g)$, given the enthalpy change for the following reaction and the $\Delta_f H$ of ethene, $C_2H_4(g)$, which is +52 kJ mol^{-1}.

$$C_2H_4(g) + H_2(g) \rightarrow C_2H_6(g) \qquad \Delta H = -137\ kJ\ mol^{-1}$$

4) Use the enthalpies of formation below to calculate the enthalpy change for the following reaction.

$$3\ Fe(s) + 4\ H_2O(g) \rightarrow 4\ H_2(g) + Fe_3O_4(s)$$

$\Delta_f H$: $H_2O(g)$ –242; $Fe_3O_4(s)$ –1117 kJ mol^{-1}

5) The ΔH for the following reaction is shown. Use it and the $\Delta_f H$ values below to calculate the $\Delta_f H$ of $Pb(NO_3)_2(s)$.

$$Pb(NO_3)_2(s) \rightarrow PbO(s) + 2\ NO_2(g) + \tfrac{1}{2}\ O_2(g) \qquad \Delta H = +301\ kJ\ mol^{-1}$$

$\Delta_f H$: PbO(S) –217; $NO_2(g)$ +33 kJ mol^{-1}

6) Use the enthalpies of formation below to calculate the enthalpy change for the following reaction.

$$CH_3COCH_3(l) + H_2(g) \rightarrow CH_2CH(OH)CH_3(l)$$

$\Delta_f H$: $CH_3COCH_3(l)$ –248; $CH_2CH(OH)CH_3(l)$ –318 kJ mol^{-1}