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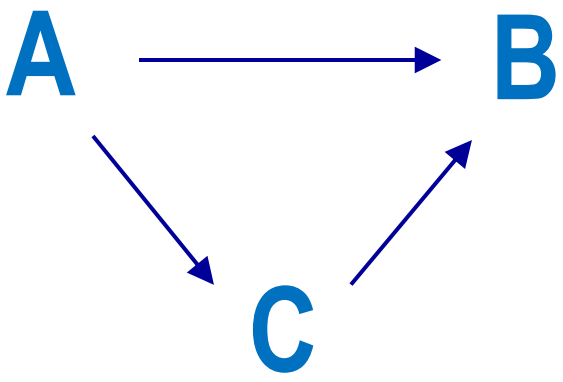
HESS'S LAW

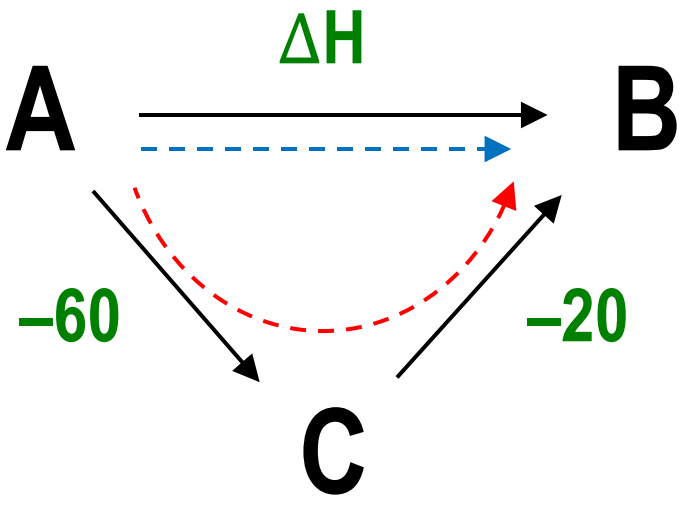
Hess's Law

The enthalpy change for a reaction is independent of the route taken



The enthalpy change for A ⟶ B
is exactly the same as from A ⟶ C ⟶ B

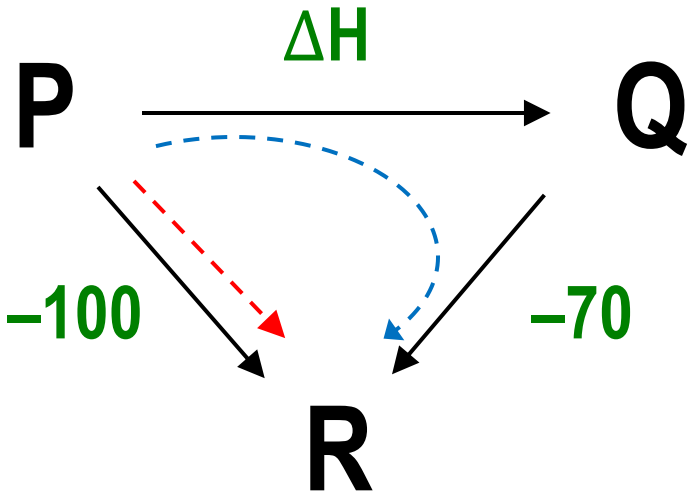
sum of the clockwise arrows = sum of anticlockwise arrows



$\Delta H = -60 + -20$

$\Delta H = -60 - 20$

$= -80$



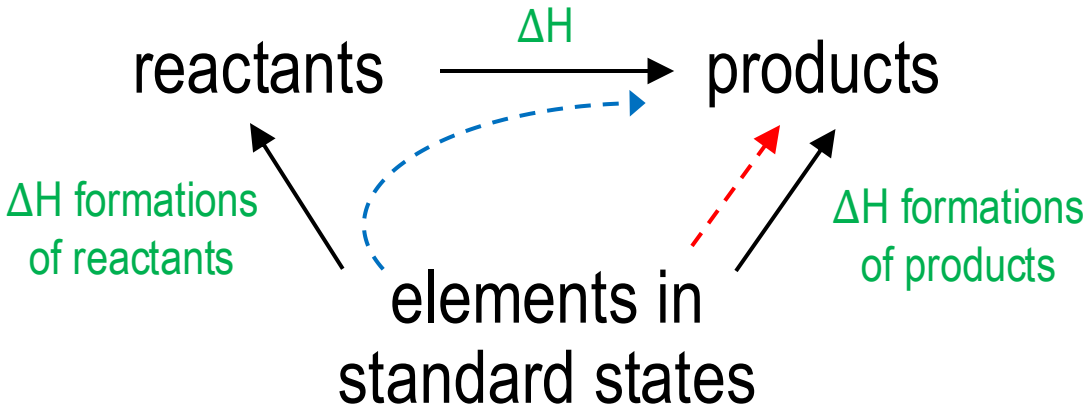
$\Delta H + -70 = -100$

$\Delta H = -100 + 70$

$= -30$

Hess's Law - ΔH Formation Questions

where all ΔH except one are ΔH formation



ΔH formations of reactants + ΔH = ΔH formations of products

ΔH = ΔH formations of products – ΔH formations of reactants

ΔH = [SUM ΔH formations of products] – [SUM ΔH formations of reactants]

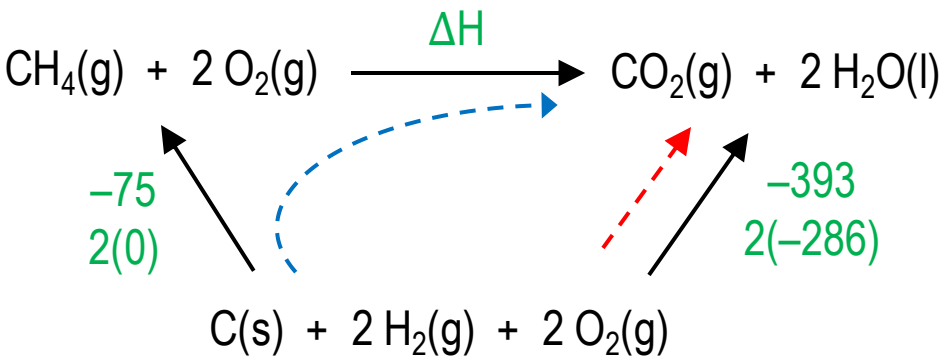
Hess's Law - ΔH Formation Questions

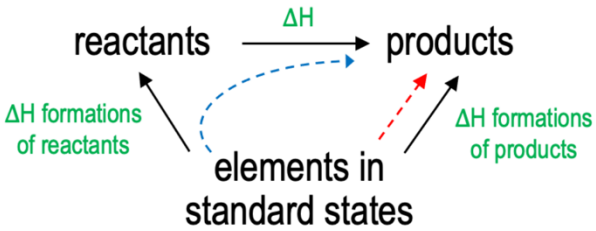
where all ΔH except one are ΔH formation

Example 1 Calculate the overall enthalpy change for this reaction using data given.

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

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





ΔH = [SUM ΔH formations of products] – [SUM ΔH formations of reactants]

ΔH = [–393 + 2(–286)] – [–75 + 2(0)]

= –890 kJ mol^{-1}

Hess's Law - ΔH Formation Questions

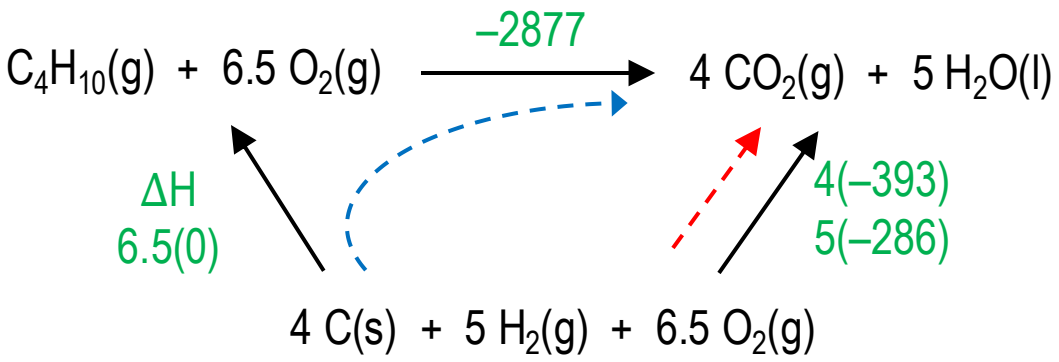
where all ΔH except one are ΔH formation

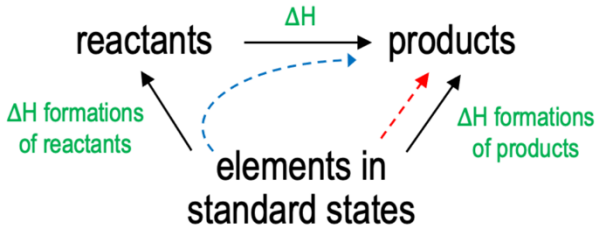
Example 2 The enthalpy change for this reaction is –2877 kJ mol^{-1}

$C_4H_{10}(g) + 6.5\ O_2(g) \rightarrow 4\ CO_2(g) + 5\ H_2O(l)$

Calculate the enthalpy of combustion of butane using this and this data:

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





ΔH = [SUM ΔH formations of products] – [SUM ΔH formations of reactants]

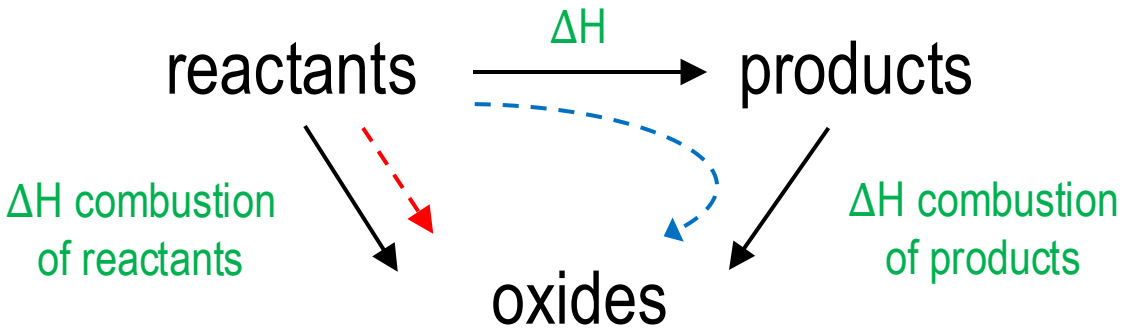
–2877 = [4(–393) + 5(–286)] – [ΔH + 6.5(0)]

ΔH = [4(–393) + 5(–286)] + 2877

= –125 kJ mol^{-1}

Hess's Law - ΔH Combustion Questions

where all ΔH except one are ΔH combustion

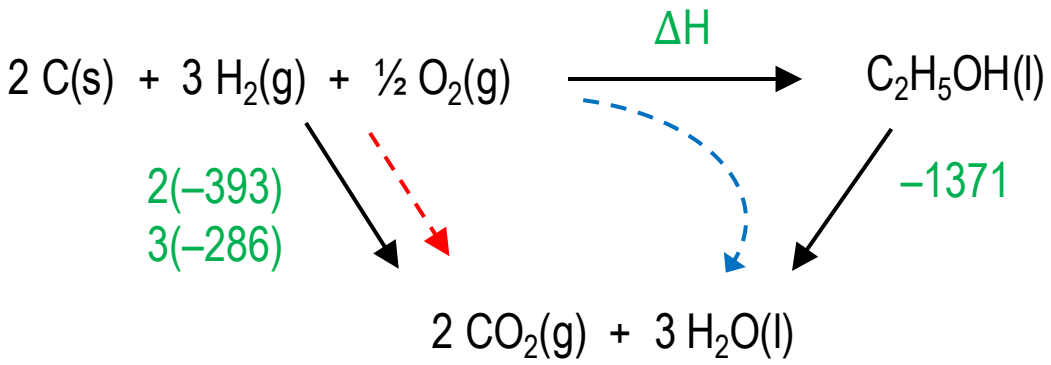


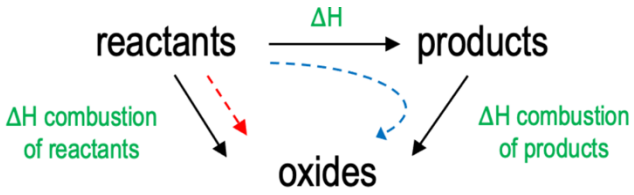
Hess's Law - ΔH Combustion Questions

where all ΔH except one are ΔH combustion

Example 3 Calculate the enthalpy of formation of ethanol given these enthalpies of combustion.

$\Delta_c H$ C(s) = –393, $H_2(g)$ = –286, $C_2H_5OH(l)$ = –1371 kJ/mol





$\Delta H - 1371 = 2(-393) + 3(-286)$

$\Delta H = 1371 + 2(-393) + 3(-286)$

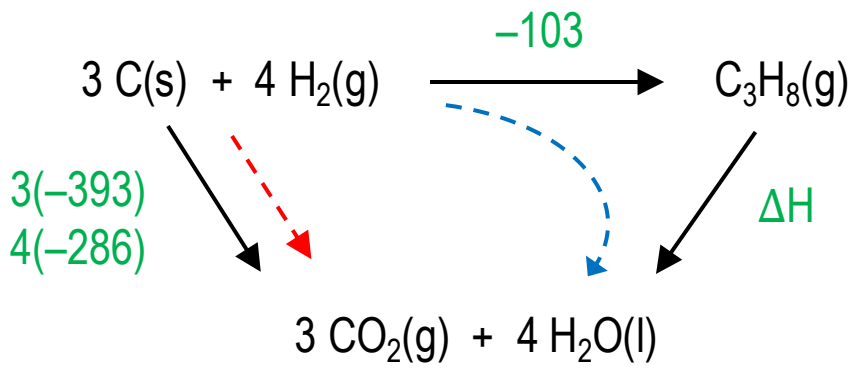
$= -273 \text{ kJ mol}^{-1}$

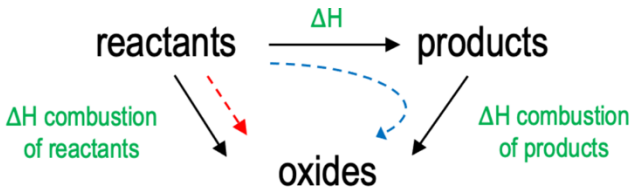
Hess's Law - ΔH Combustion Questions

where all ΔH except one are ΔH combustion

Example 4 Calculate the enthalpy of combustion of propane given these enthalpies changes.

$\Delta_c H$ C(s) = –393, $H_2(g)$ = –286 kJ/mol $\Delta_f H$ $C_3H_8(g)$ = –103 kJ/mol





$-103 + \Delta H = 3(-393) + 4(-286)$

$\Delta H = 103 + 3(-393) + 4(-286)$

$= -2220 \text{ kJ mol}^{-1}$

Hess's Law - ΔH Bond enthalpy Questions

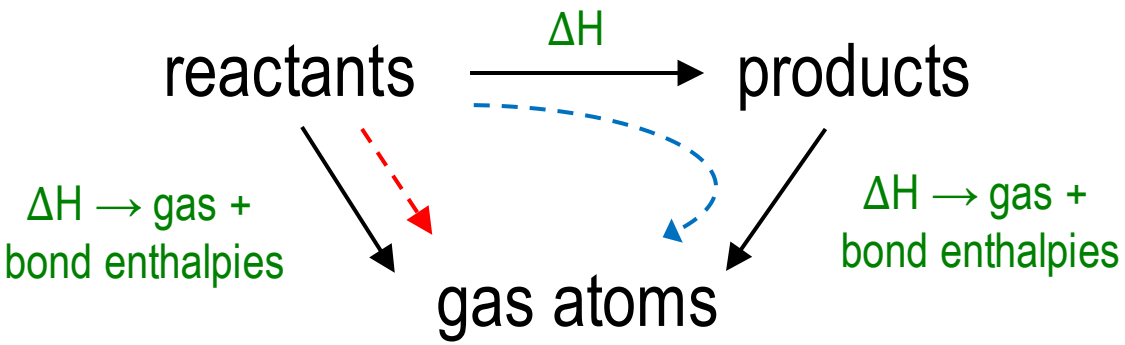
where you have some bond enthalpies

Bond enthalpy = enthalpy change to break one mole of covalent bonds in gaseous state

The exact bond enthalpy for a similar bond (e.g. C-H) varies from one compound to another, so mean values are used.

(but some bonds are unique, e.g. H-H is only in H_2 so is not a mean value)

Enthalpy changes worked out this way are only approximate therefore.



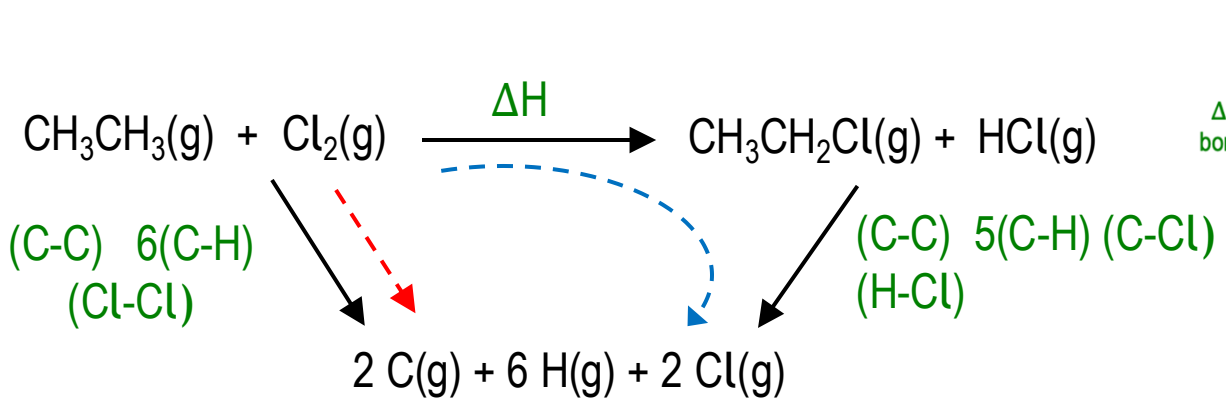
Hess's Law - ΔH Bond enthalpy Questions

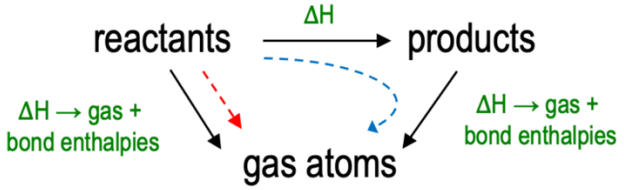
where you have some bond enthalpies

Example 5 Calculate the enthalpy change for this reaction using the bond enthalpies given.

$CH_3CH_3(g) + Cl_2(g) \rightarrow CH_3CH_2Cl(g) + HCl(g)$

Bond enthalpies: C-C 348, C-H 412, Cl-Cl 242, C-Cl 338, H-Cl 431 kJ/mol





$\Delta H + (C\text{-}C) + 5(C\text{-}H) + (C\text{-}Cl) + (H\text{-}Cl) = (C\text{-}C) + 6(C\text{-}H) + (Cl\text{-}Cl)$

$\Delta H = (C\text{-}C) + 6(C\text{-}H) + (Cl\text{-}Cl) - (C\text{-}C) - 5(C\text{-}H) - (C\text{-}Cl) - (H\text{-}Cl)$

$\Delta H = 348 + 6(412) + 242 - 348 - 5(412) - 338 - 431$

$= -115 \text{ kJ mol}^{-1}$

Hess's Law - ΔH Bond enthalpy Questions

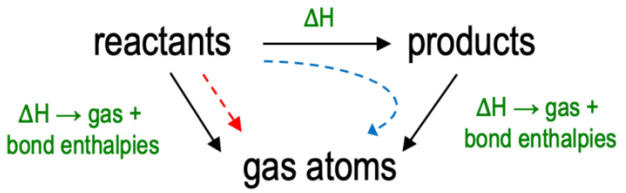
where you have some bond enthalpies

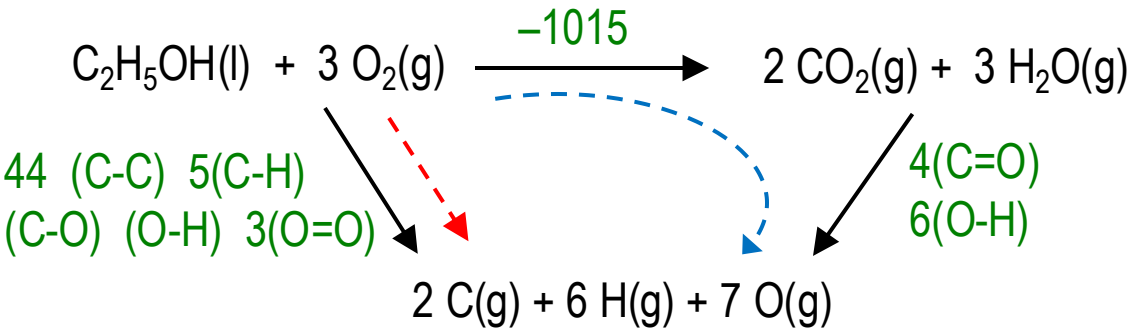
Example 6 Calculate the C-C bond enthalpy in ethanol.

$C_2H_5OH(l) + 3\ O_2(g) \rightarrow 2\ CO_2(g) + 3\ H_2O(g)$ $\Delta H = -1015$ kJ/mol

Bond enthalpies: C-H 412, C-O 360, O-H 463, C=O 743, O=O 498 kJ/mol

Enthalpy of vaporisation of ethanol = +44 kJ/mol





$-1015 + 4(C=O) + 6(O-H) = 44 + (C-C) + 5(C-H) + (C-O) + (O-H) + 3(O=O)$

$(C-C) = -1015 + 4(C=O) + 6(O-H) - 5(C-H) - (C-O) - (O-H) - 3(O=O) - 44$

$(C-C) = -1015 + 4(743) + 6(463) - 5(412) - 360 - 463 - 3(498) - 44$

$= +314$ kJ mol^{-1}

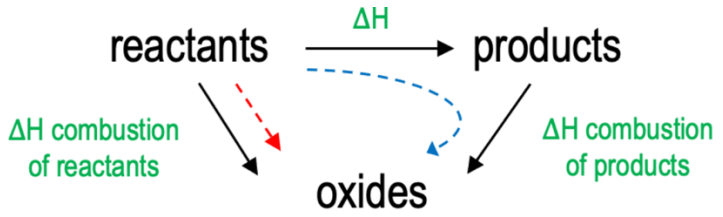
ADVICE

where all ΔH except one are ΔH formation

USE ΔH = [SUM ΔH formations of products] – [SUM ΔH formations of reactants]

where all ΔH except one are ΔH combustion

USE



where you have some bond enthalpies

USE