CONCEPT: HESS'S LAW

Rearrangement of Thermochemical Equations

● Recall, a *thermochemical equation* is a chemical equation that includes an *enthalpy of reaction*.

□ The thermochemical equation and its enthalpy of reaction (ΔH_{rxn}), are _______________ proportional.

- This means that any change to the original reaction will cause the same change in the ΔH_{rxn}.

Original Reaction

$$2\ Mg\ (s) + O_2\ (g) \longrightarrow 2\ MgO\ (s) \quad \Delta H = -1204\ kJ$$

Rearrangements

Multiplication	Division	Reverse
□ **Mutiply reaction: Multiply ΔH_{rxn}**	□ **Divide reaction: Divide ΔH_{rxn}**	□ **Reversing: Reverse sign of ΔH_{rxn}**
$2\ Mg\ (s) + 1\ O_2\ (g) \longrightarrow 2\ MgO\ (s)$ ___	$2\ Mg\ (s) + 1\ O_2\ (g) \longrightarrow 2\ MgO\ (s)$ ___	$2\ Mg\ (s) + 1\ O_2\ (g) \longrightarrow 2\ MgO\ (s)$
__ Mg (s) + __ O_2 (g) ⟶ __ MgO (s)	__ Mg (s) + __ O_2 (g) ⟶ __ MgO (s)	
ΔH_{rxn} = ___________	ΔH_{rxn} = ___________	ΔH_{rxn} = ___________

EXAMPLE: If the formation equation for boron trioxide is given as the following:

$$4\ B\ (s) + 3\ O_2\ (g) \longrightarrow 2\ B_2O_3\ (s) \quad \Delta H_{rxn} = -\ 2547\ kJ$$

what will be the new enthalpy value when it is rearranged?

$$4\ B_2O_3\ (s) \longrightarrow 8\ B\ (s) + 6\ O_2\ (g) \quad \Delta H_{rxn} = ?$$

PRACTICE: Calculate the ΔH_{rxn} for the following thermochemical equation:

$$S\ (s) + \frac{3}{2}\ O_2\ (g) \longrightarrow SO_3\ (s) \quad \Delta H_{rxn} = ?$$

When given the following:

$$2\ S\ (s) + 3\ O_2\ (g) \longrightarrow 2\ SO_3\ (s) \quad \Delta H_{rxn} = -\ 296.8\ kJ$$

CONCEPT: HESS'S LAW

Applying Hess's Law

● Many reactions cannot be carried out in a single step, but instead require multiple steps to get the final product.

□ **Hess's Law** states that the **ΔH_{rxn}** of an **overall reaction** is the sum of the **ΔH°** values of these multiple steps.

Partial Reaction 1: $XeF_2\ (s) \longrightarrow Xe\ (g) + F_2\ (g)$ $\Delta H° = +123\ kJ$

Partial Reaction 2: $Xe\ (g) + 2\ F_2\ (g) \longrightarrow XeF_4\ (s)$ $\Delta H° = -262\ kJ$

Overall Reaction: $XeF_2\ (s) + F_2\ (g) \longrightarrow XeF_4\ (s)$ $\Delta H_{rxn} = -139\ kJ$

EXAMPLE: Calculate the ΔH_{rxn} for overall reaction

$$CO\ (g) + NO\ (g) \longrightarrow CO_2\ (g) + \frac{1}{2} N_2\ (g) \qquad \Delta H_{rxn} = ?$$

when given the following set of partial reactions:

$$CO_2\ (g) \longrightarrow CO\ (g) + \frac{1}{2} O_2\ (g) \qquad \Delta H° = 283.0\ kJ$$

$$N_2\ (g) + O_2\ (g) \longrightarrow 2\ NO\ (g) \qquad \Delta H° = 180.6\ kJ$$

STEP 1: Start with the first compound in the overall equation and **locate** it in the set of partial reactions.

□ Compound from partial reaction must match (__________ , __________) with the one from the overall equation.

- This may require you to reverse, multiply or divide the partial reaction, which will also affect **ΔH°**.

STEP 2: Keep moving onto the next compound in the overall equation until you **locate** all compounds in partial reactions.

STEP 3: Combine the partial reactions and **cross out** reaction intermediates if present.

□ **Reaction Intermediates**: Compounds that look the same, with one as a reactant and the other a product.

STEP 4: Add up all the **ΔH°** values to obtain **ΔH_{rxn}** of the overall reaction.

<u>CONCEPT:</u> <u>HESS'S LAW</u>

PRACTICE: Calculate the ΔH_{rxn} for

$$S\,(s) + \frac{3}{2}\,O_2\,(g) \longrightarrow SO_3\,(g) \qquad \Delta H_{rxn} = ?$$

Given the following set of reactions:

$$\mathbf{\frac{1}{2}}\,S\,(s) + \frac{1}{2}\,O_2\,(g) \longrightarrow \mathbf{\frac{1}{2}}\,SO_2\,(g) \qquad \Delta H^\circ = -296.8\text{ kJ}$$

$$2\,SO_3\,(g) \longrightarrow 2\,SO_2\,(g) + O_2\,(g) \qquad \Delta H^\circ = 198.4\text{ kJ}$$

PRACTICE: Calculate the ΔH_{rxn} for

$$ClF\,(g) + F_2\,(g) \longrightarrow ClF_3\,(g) \qquad \Delta H_{rxn} = ?$$

Given the following reactions:

$$Cl_2O\,(g) + F_2O\,(g) \longrightarrow 2\,ClF\,(g) + O_2\,(g) \qquad \Delta H^\circ = -167.4\text{ kJ}$$

$$4\,ClF_3\,(g) + 4\,O_2\,(g) \longrightarrow 2\,Cl_2O\,(g) + 6\,F_2O\,(g) \qquad \Delta H^\circ = 682.8\text{ kJ}$$

$$2\,F_2\,(g) + O_2\,(g) \longrightarrow 2\,F_2O\,(g) \qquad \Delta H^\circ = -181.7\text{ kJ}$$