N3 - THERMOCHEMISTRY

Hess's Law

Link to YouTube Presentation: https://youtu.be/5NDv9TwaVXw

Reminder…

There are going to be WAY more words on these slides than you need to write down. WAY more than in my Honors Chem lecture slides. A huge part of AP Chem is constantly going back and reviewing previous material, self studying, etc. So my slides are formatted so that when you come back to them you have a bit more "verbiage" there to help you!

DO NOT COPY EVERYTHING DOWN DURING LECTURE!

If you think you need to add more detail after class, that is why we do annotations as a homework assignment after we've taken the notes! Listen to me talking, take down *notes* and review and add to your notes later.

You are not a PHOTOCOPIER! You are a NOTE TAKER!

N3 - THERMOCHEMISTRY

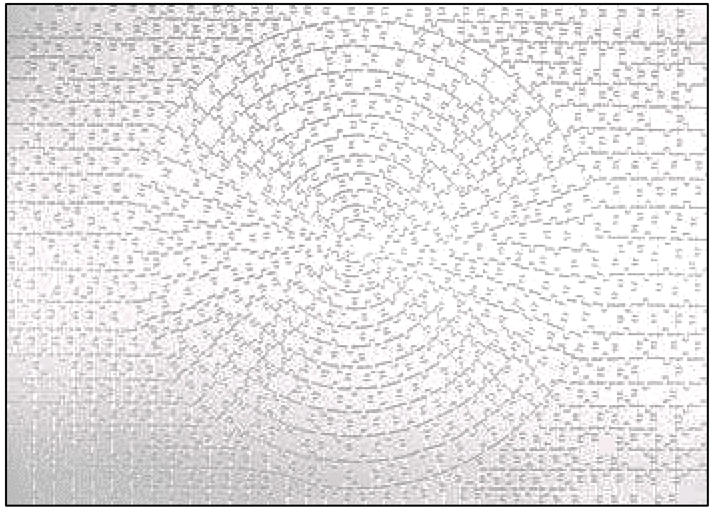
Hess's Law

Target: I can use Hess's Law to calculate the unknown total enthalpy change during a reaction by adding together individual baby steps that I do know the enthalpy change for.

Its just a puzzle!

Sometimes it’s a really hard puzzle…
but it’s still just a puzzle!

All the pieces are there,
you just have to figure out how to put them together…

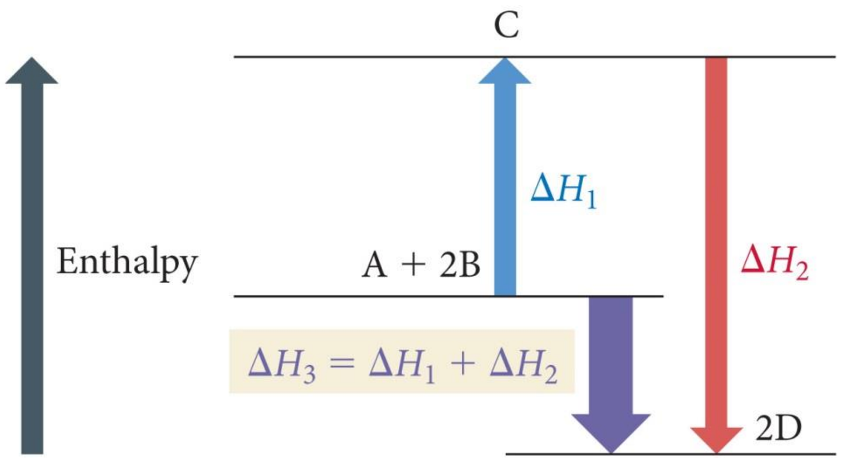


Unfortunately, no real “tricks” for how to figure out which parts to put together.

Hess's Law

"In going from a particular set of reactants to a particular set of products, the change in enthalpy is the same whether the reaction takes place in one step or a series of steps."

Hess's Law
The change in enthalpy for a stepwise process is the sum of the enthalpy changes of the steps.



First...What is "Enthalpy" ????

It is related to energy.

It takes into account any change in pressure and volume.

E = energy

H = E + PV (pressure, volume)

We assume our reactions are not at crazy high pressures, and that they do not have crazy changes in volume.

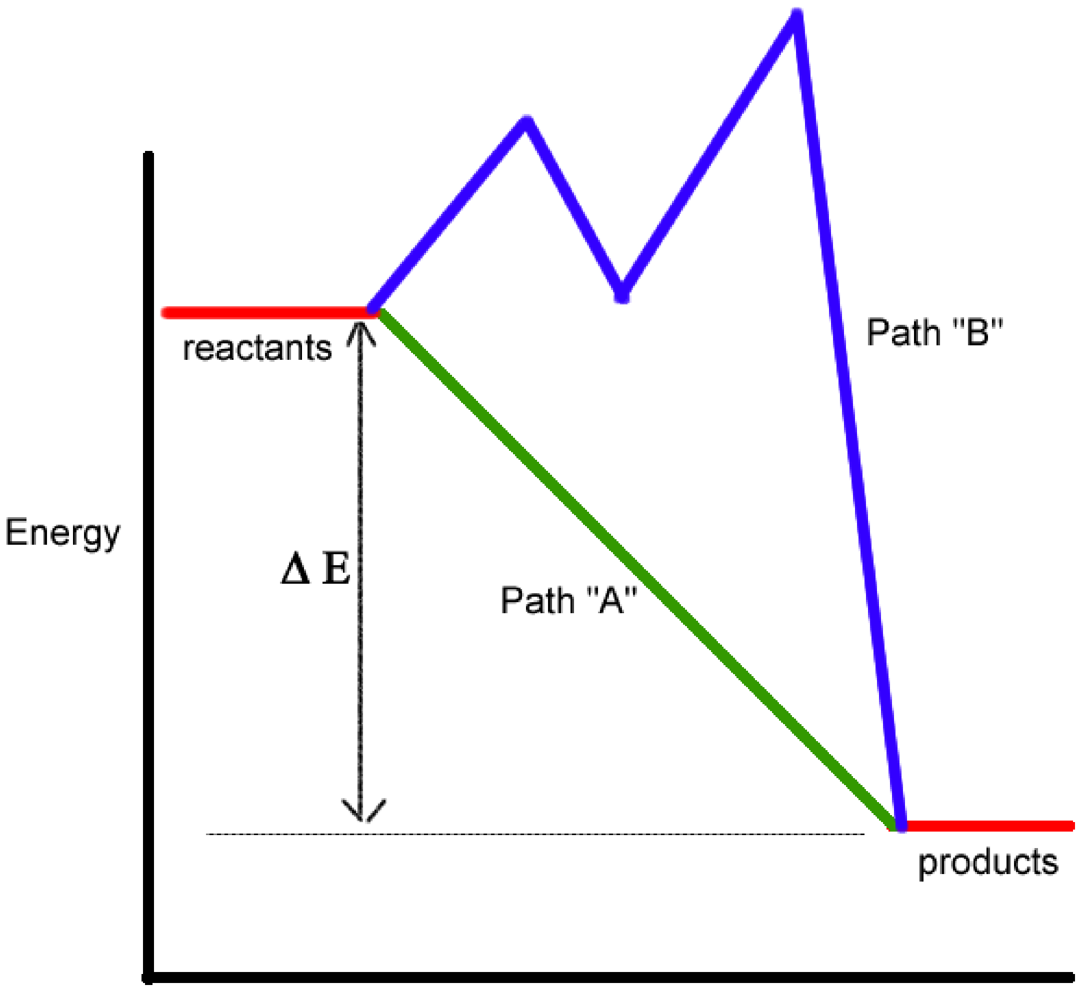
So.... PV is *negligible.*

So from a practical standpoint in this class... H = E

Hess's Law

Path A – Mrs. Farmer cleaning the house.

Path B – Mr. Farmer cleaning the house.



Regardless of the path taken, you still get to the same place.

Although Path B drives Mrs. Farmer bonkers – Ha!

Relationships Involving ΔH_{rxn}

Multiplying Rxn by a # to Change Coefficients

ΔH_{rxn} is multiplied by that factor.

- Because ΔH_{rxn} is *extensive* – depends on the amount of substance

$C(s) + O_2(g) \rightarrow CO_2(g)$ $\Delta H = -393.5$ kJ/mol_{rxn}

2 $C(s)$ + **2** $O_2(g) \rightarrow$ **2** $CO_2(g)$ ΔH = **2 x** (−393.5 kJ) = −787.0 kJ/mol_{rxn}

Reversing a rxn to flip which side the products/reactants are on

Flip the sign of ΔH, if positive now negative, if negative, now positive

$C(s) + O_2(g) \rightarrow CO_2(g)$ $\Delta H = -393.5$ kJ/mol_{rxn}

$CO_2(g) \rightarrow C(s) + O_2(g)$ ΔH = **−** (−393.5) = **+** 393.5 kJ/mol_{rxn}

Standard Conditions

Standard State

The state of a material at a defined set of conditions.

- Pure gas at **1 atm** pressure
- Substances in a solution with a **1M** concentration
- Pure solid or liquid in its **most stable form** at 1 atm pressure and temperature of interest (**usually 25°C**)

Standard Enthalpy Change

Standard Enthalpy Change

ΔH° - the Enthalpy change when all reactants and products are in their standard states.

That's what the ° symbol means – that it is under the standard conditions. You can have ΔH values that are not at standard conditions, then you leave the ° off.

Standard Enthalpy of Formation

Standard Enthalpy of Formation

$\Delta H°_f$ - the Enthalpy change for the reaction forming ***1 mole*** of a pure compound from its ***elements.***

NO! $2H_2 + O_2 \rightarrow 2\ H_2O$ $\Delta H_f = -572\ kJ/mol_{rxn}$

YES! $H_2 + \frac{1}{2}\ O_2 \rightarrow H_2O$ $\Delta H°_f = -286\ kJ/mol_{rxn}$

- Elements must be in their standard states
- **$\Delta H°_f$ for a pure element in its standard state = 0 kJ/mol_{rxn}**

That includes diatomic gases! They are still pure elements!

Hess's Law Example Problem #1

Calculate ΔH for the combustion of methane, CH_4:

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

#	Reaction	ΔHº
1	$C + 2H_2 \rightarrow CH_4$	-74.80 kJ
2	$C + O_2 \rightarrow CO_2$	-393.50 kJ
3	$H_2 + ½ O_2 \rightarrow H_2O$	-285.83 kJ

Step #1:

CH_4 must appear on the reactant side, so we reverse reaction #1 and change the sign on ΔH.

- rxn 1 **$CH_4 \rightarrow C + 2H_2$** **+74.80 kJ**

Hess's Law Example Problem #1

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2	$C + O_2 \rightarrow CO_2$	-393.50 kJ
3	$H_2 + ½ O_2 \rightarrow H_2O$	-285.83 kJ

Step #2:

Keep reaction #2 unchanged, because CO_2 belongs on the product side

- rxn 1	$CH_4 \rightarrow C + 2H_2$	+74.80 kJ
rxn 2	$C + O_2 \rightarrow CO_2$	-393.50 kJ

Hess's Law Example Problem #1

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Step #3:

Use reaction #3 to get water as a product, but multiply it by 2 since you have 2 H_2O

- rxn 1	**$CH_4 \rightarrow C + 2H_2$**	**+74.80 kJ**
rxn 2	**$C + O_2 \rightarrow CO_2$**	**-393.50 kJ**
2 x rxn 3	**$2H_2 + O_2 \rightarrow 2H_2O$**	**2 x (-285.83 kJ)**

Hess's Law Example Problem #1

Calculate ΔH for the combustion of methane, CH_4:

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Step #4:

Cross out things that show up on both sides, then sum up your ΔH values

- rxn 1	$CH_4 \rightarrow$ ~~C~~ + ~~$2H_2$~~	**+74.80 kJ**
rxn 2	~~C~~ + $O_2 \rightarrow CO_2$	**-393.50 kJ**
2 x rxn 3	~~$2H_2$~~ + $O_2 \rightarrow 2H_2O$	**2 x (-285.83 kJ)**

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ -890.36 kJ /mol_{rxn}

Hess's Law Example Problem #2

2 NOCl (*g*) → N_2 (*g*) + O_2 (*g*) + Cl_2 (*g*) Δ*H* = ?

Rxn #1)	½ N_2 (*g*) + ½ O_2 (*g*) → NO (*g*)	Δ*H* = 90.3 kJ
Rxn #2)	NO (*g*) + ½ Cl_2 (*g*) → NOCl (*g*)	Δ*H* = –38.6 kJ

A -51.7 kJ

B 51.7 kJ

C -103.4 kJ

D 103.4 kJ

E 142.0 kJ

Hess's Law Example Problem #2

$2\ NOCl\ (g) \rightarrow N_2\ (g) + O_2\ (g) + Cl_2\ (g)$ $\Delta H =$?

Rxn #1) $\frac{1}{2} N_2\ (g) + \frac{1}{2} O_2\ (g) \rightarrow NO\ (g)$	$\Delta H =$	90.3 kJ
Rxn #2) $NO\ (g) + \frac{1}{2} Cl_2\ (g) \rightarrow NOCl\ (g)$	$\Delta H =$	–38.6 kJ

A -51.7 kJ

B 51.7 kJ

C **-103.4 kJ**

D 103.4 kJ

E 142.0 kJ

Rxn #	How to change it	Rxn	ΔH
2	- and x 2	$2\ NOCl \rightarrow$ ~~2NO~~ $+ Cl_2$	-2 (-38.6)
1	- and x 2	~~2NO~~ $\rightarrow N_2 + O_2$	- 2 (90.3)
		$2NOCl \rightarrow N_2 + O_2 + Cl_2$	-103.4 kJ

Hess's Law Example Problem #3

$FeO(s) + CO(g) \rightarrow Fe(s) + CO_2(g)$ Calculate ΔH°_{rxn}

Rxn #1)	$3Fe_2O_3 + CO\ (g) \rightarrow 2Fe_3O_4 + CO_2\ (g)$	ΔH°= -47 kJ
Rxn #2)	$Fe_2O_3 + 3CO\ (g) \rightarrow 2Fe\ (s) + 3CO_2\ (g)$	ΔH°= -25 kJ
Rxn #3)	$Fe_3O_4 + CO\ (g) \rightarrow 3FeO\ (s) + CO_2\ (g)$	ΔH°= 19 kJ

A -53 kJ

B -3 kJ

C -41 kJ

D 22 kJ

E -11 kJ

Hess's Law Example Problem #3

$FeO(s) + CO(g) \rightarrow Fe(s) + CO_2(g)$ Calculate ΔH°_{rxn}

Rxn #1) $3Fe_2O_3 + CO(g) \rightarrow 2Fe_3O_4 + CO_2(g)$ $\Delta H^{\circ} = -47$ kJ
Rxn #2) $Fe_2O_3 + 3CO(g) \rightarrow 2Fe(s) + 3CO_2(g)$ $\Delta H^{\circ} = -25$ kJ
Rxn #3) $Fe_3O_4 + CO(g) \rightarrow 3FeO(s) + CO_2(g)$ $\Delta H^{\circ} = 19$ kJ

A -53 kJ
B -3 kJ
C -41 kJ
D 22 kJ
E **-11 kJ**

Rxn #	How to change it	Rxn	ΔH
3	- and x 1/3	$FeO + \frac{1}{3}CO_2 \rightarrow \frac{1}{3}Fe_3O_4 + \frac{1}{3}CO$	$-\frac{1}{3}(19)$
2	x 1/2	$\frac{1}{2}Fe_2O_3 + \frac{3}{2}CO \rightarrow Fe + \frac{3}{2}CO_2$	$\frac{1}{2}(-25)$
1	- and x 1/6	$\frac{1}{3}Fe_3O_4 + \frac{1}{6}CO_2 \rightarrow \frac{1}{2}Fe_2O_3 + \frac{1}{6}CO$	$-\frac{1}{6}(-47)$
		$FeO + CO \rightarrow Fe + CO_2$	-11 kJ

Reminder About Units

Usually people just use: kJ or kJ/mol

College board started using: **kJ/mol_{rxn}**

Which makes sense in terms of doing good dimensional analysis. It is the energy released when you perform the reaction ONE TIME THE WAY IT IS WRITTEN. The energy released when you do the reaction once with the mole ratios given. If you double the moles, you double the energy because you are doing the reaction twice.

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Example:

$H_2 + ½\ O_2 \rightarrow H_2O$ $\Delta H°_f = -286\ kJ/mol_{rxn}$

What if you wanted to know the energy released when forming water if you had 100g $O_2(g)$ to start with?

100 g O_2	1 mol O_2	1 mol_{rxn}	-286 kJ	= -1788 kJ
	32 g O_2	0.5 mol O_2	1 mol_{rxn}	

Reminder About Units

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Example:

$H_2 + \frac{1}{2} O_2 \rightarrow H_2O$ $\Delta H°_f = -286\ kJ/mol_{rxn}$

What if you wanted to know the energy released when forming water if you had 100g O_2(g) to start with?

100 g O_2	1 mol O_2	1 rxn	-286 kJ	= -1788 kJ
	32 g O_2	0.5 mol O_2	1 rxn	

Reminder About Units

Usually people just use: kJ or kJ/mol

College board started using: **kJ/mol_{rxn}**

I admit, I often don't use kJ/mol_{rxn} because it isn't as traditional. I've gone a lot of years using kJ or kJ/mol. You should be better and use what college board likes because they are the ones grading your AP Exam! Ha! Also, on harder problems it actually can make things easier when trying to convert units.

Its just a puzzle!

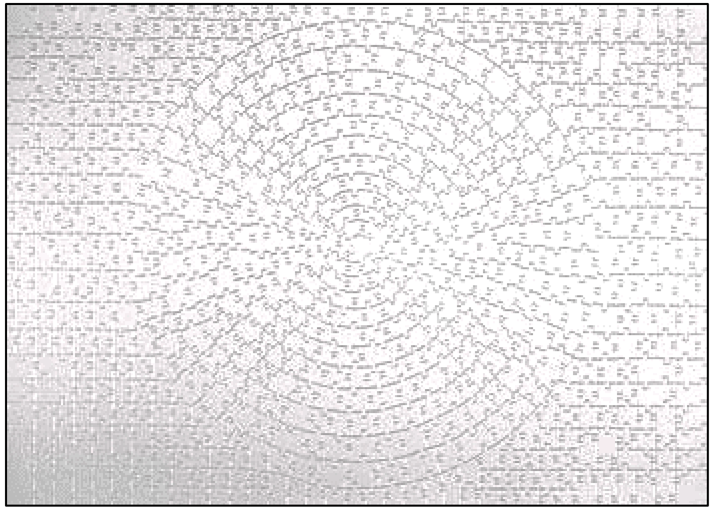
Keep calm and do the puzzle!

Erase when needed!

Don’t squish your work!

Count carefully!

Ask for help!



YouTube Link to Presentation

https://youtu.be/5NDv9TwaVXw