

evolved: E lost

is a reaction exo/endo?

- 1) In the reaction mixture there are \_\_\_\_\_ ions. \_\_\_\_\_ are spectator ions
- 2) The formation of \_\_\_\_\_ bonds releases more E than required to overcome ion-dipole interactions between \_\_\_\_\_ and their solvation shells. Therefore, the reaction is exothermic.

# Thermodynamics

predicts if a reaction would occur at given temp

## Gibbs free energy

ΔG = ΔH - TΔS

(kJ mol<sup>-1</sup>)      enthalpy      entropy

ΔH, ΔS remain constant  
true if no phase change

ΔG < 0 spontaneous

ΔG > 0 non-spontaneous

ΔG = 0 Equilibrium

Thermochemical eq  
• need the state

**Enthalpy (H)**

- thermal stability of substance
- H ↓ more stable

Only ΔH can be measured

T = 298K or 25°C  
P = 1 bar  
temperature  
pressure  
amount  
physical state

ΔH > 0 if energy of the system ↑  
if energy of the system ↓ Energy given out

bonds breaking: need energy  
bonds form: E released

thermochemical equation  
↳ both eq + E change

How to determine ΔH

Direct

• calorimeter/  
bomb calorimeter

Indirect

bond breaking

only covalent

①

Bond energy

- energy absorbed to break 1 mol of covalent bonds between atoms in a diatomic gaseous molecule or a particular type of bond in a gaseous polyatomic molecule to give gaseous atoms
- Average vals of E required to break a particular bond in diff molecules

eg HCl(g) → H(g) + Cl(g)

break E > 0  
form E < 0

xY(g) → xY(g) + Y(g)  
ΔH = BE(x-Y)

- always positive
- average values (est will vary from exp. vals)

Energy required to break a chemical bond = amount of energy released when the same chemical bond is formed.

ΔH of xY(g) + Y(g) → xY(g) is just the negative of x-Y

ΔH = ΔH<sub>bond breaking</sub> - ΔH<sub>bond forming</sub>

physical / chemical form that is stable at normal P atm  
eg. O<sub>2</sub>(g)

H<sub>f</sub><sup>0</sup> for an element is 0

"shortcut for bond break - bond form"

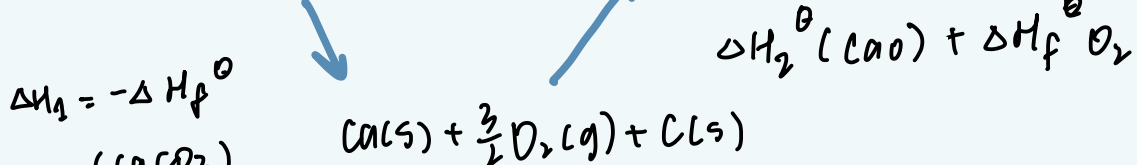
## Standard Enthalpy change of formation

ΔH<sub>f</sub><sup>0</sup>

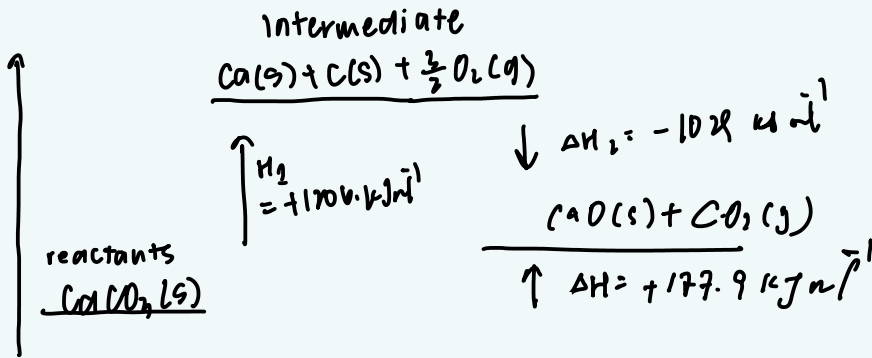
Change when one mole of a pure substance is formed from its constituent elements in their standard states under standard conditions of 298K and 1 bar.

ΔH<sub>r</sub><sup>0</sup> = Σ n ΔH<sub>f</sub><sup>0</sup> (products) - Σ m ΔH<sub>f</sub><sup>0</sup> (reactants)

ΔH<sub>r</sub><sup>0</sup> → v d k if (s) / (l) / (g)

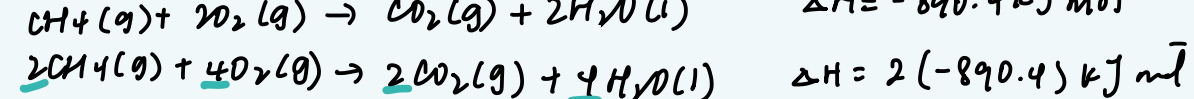


ΔH = ΔH<sub>1</sub> + ΔH<sub>2</sub>  
= ΔH<sub>f</sub><sup>0</sup>(CaO(s)) + ΔH<sub>f</sub><sup>0</sup>(CO<sub>2</sub>) - ΔH<sub>f</sub><sup>0</sup>(CaCO<sub>3</sub>)

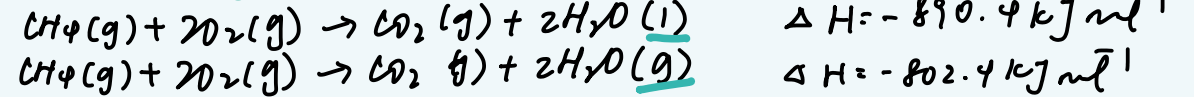


## Δ characteristics of ΔH

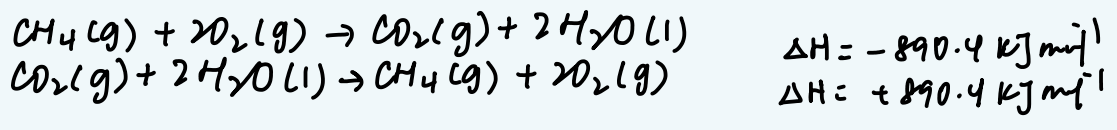
1) Amt of substance



2) State symbols

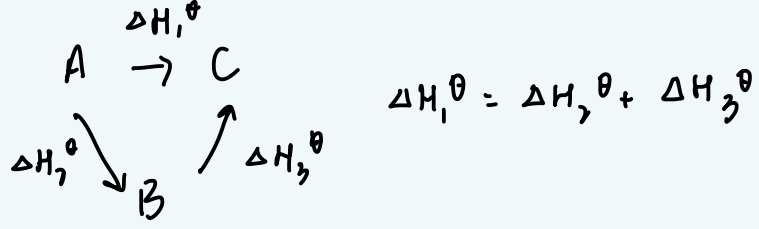


3) ΔH forward & backward (opposite in magnitude)

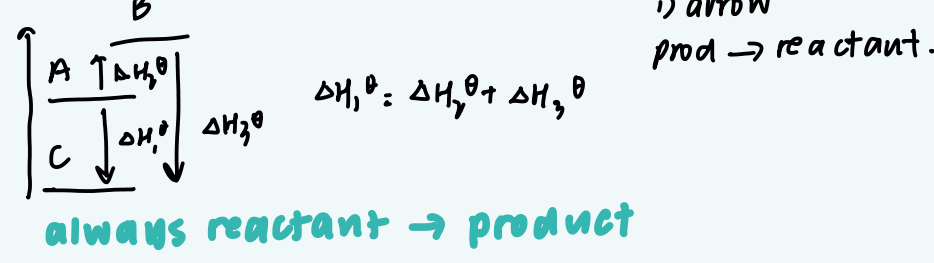


**Hess's law** (as long as start and end are same)  
enthalpy change accompanying a chemical reaction stays the same regardless of the route by which the chemical change occurs, provided the initial and final conditions are the same.

## 1) Energy cycle diagram



## 2) Energy level diagram



↑ arrow  
prod → reactant