

5.1 Measuring Energy Changes

Energy: measure of ability to do work

forms: heat, light, sound, electricity, chemical energy

Heat: mode of energy transfer due to temp diff
& produces an \uparrow in disorder (entropy) in how particles behave

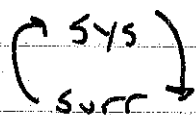
System vs. Surroundings

Surroundings: everything else

System: area of interest (ex??)

open: energy & matter exchange w/ surroundings

closed: exchange energy, not matter w/ surr.

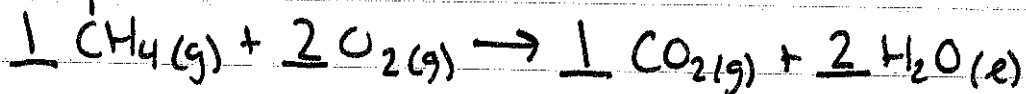


total energy is same, just
where is it at

Enthalpy: heat content of substance $\rightarrow \Delta H$ (change in heat)
 \rightarrow total energy of a system (stored in bonds & IMFs)

Exothermic rxn: transfer heat from sys \rightarrow surr
• most chm rxns (including all combustion & neutralization)

example:



$$\Delta H = \textcircled{-} 890 \text{ kJ mol}^{-1}$$

direction of
energy

energy per mole of
reactant

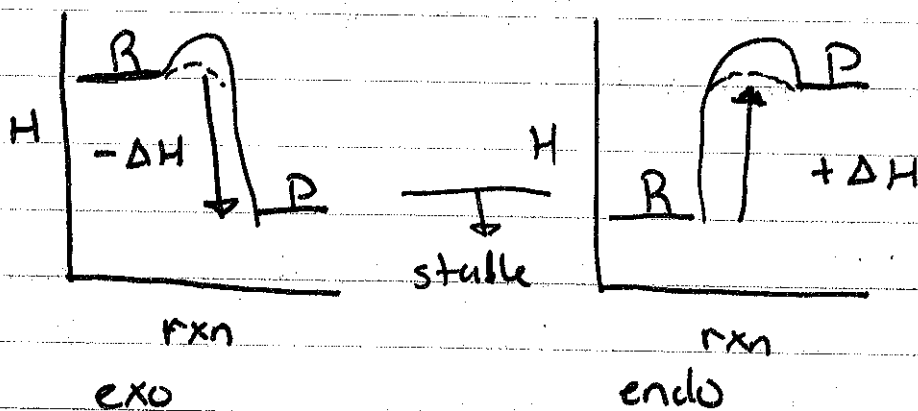
Endothermic rxn: energy transfer $\text{surr} \rightarrow \text{sys}$
 • fewer rxns due to reactants being more stable than products

example:



$$\Delta H = \textcircled{+} 2802.5 \text{ kJ mol}^{-1}$$

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Standard enthalpy changes (ΔH^\ominus) - controlled conditions

$$P = 100 \text{ kPa}$$

$$m = 1 \text{ mol dm}^{-3} \text{ (all solns)}$$

substances in std state

$$(T = 298 \text{ K})$$

Calculations:

Temp: measure of avg kinetic energy

Kelvin (K): emphasizes relationship between avg KE + temp.

ΔT depends on:

- mass of object
- heat added
- nature of substance (IMFs)

specific heat capacity: heat needed to $\uparrow T$ of mass by 1K

heat change (q) = mass (m) x s.h.c. (c) x Change in temp (ΔT)

\downarrow 1K change = 1°C change

vs.

heat capacity: heat needed to $\uparrow T$ of an object by 1K

- distinguish relationship b/w diff objects

$$\text{heat capacity (C)} = \frac{\text{heat change (q)}}{\Delta T}$$

ex: 10.0g Cu, $c = 0.385 \text{ Jg}^{-1}\text{C}^{-1}$, $\Delta T = 85^\circ\text{C to } 25^\circ\text{C}$

$q = mc\Delta T$

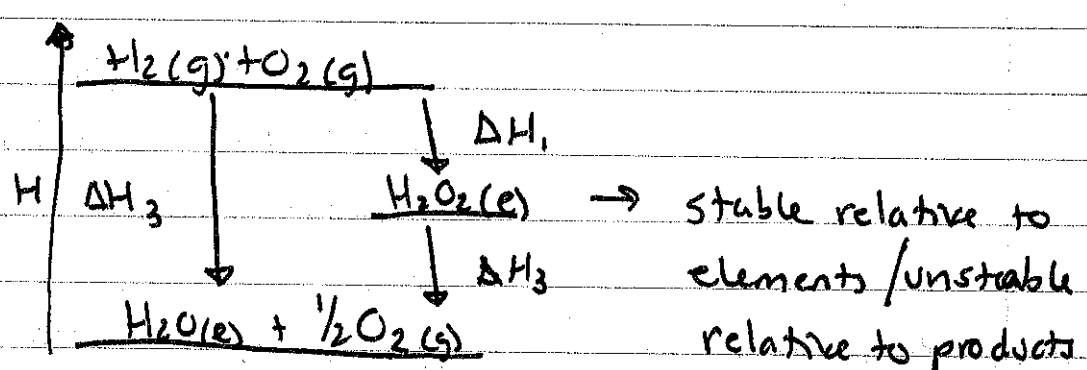
$(10)(0.385)(-60) = -231 \text{ J}$

Enthalpy changes & direction

↳ usually to lower stored energy

• exothermic rxn: products are more stable than reactants (explain why)

• stability diagram

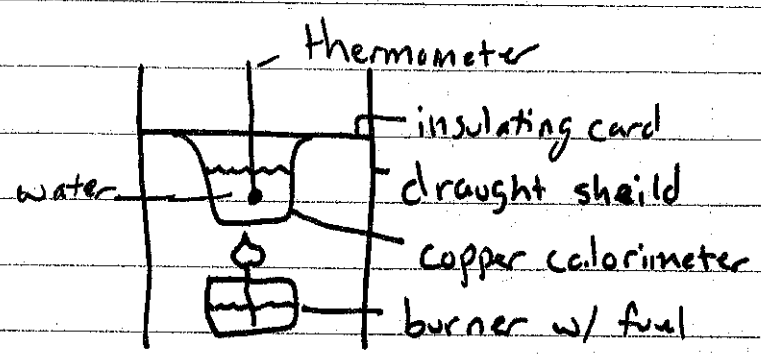


• endo \leftarrow rare but do occur

Heat of combustion

std enthalpy change of combustion (ΔH_c^\ominus) is enthalpy change for complete combustion of one mole of a substance in its std state in excess O_2 under std conditions

Calorimeter set up



$T_{H_2O} \uparrow$ due to heat given off by combustion

* assume all heat absorbed by H₂O

∴ heat change rxn = - heat change H₂O (-mcΔT)

ΔH- ΔH+ ΔT↑ exo

ΔH+ ΔH- ΔT↓ endo

unit: kJ mol⁻¹ (heat dependent on moles rxn)

sig fig

example:

mass H₂O: 200.00g

ΔT (°C): +13.00

mass ethanol: 0.45g

1. Calculate moles: m(C₂H₅OH) / M(C₂H₅OH) = 0.45g / 46.08g = 0.00976 moles

2. Calculate heat produced: q_{H2O} = m_{H2O} × C_{H2O} × ΔT_{H2O} = (200.00)(4.18)(13) = 10,868 J

3. Calculate energy of fuel: ΔH_{rxn} = -ΔH_{H2O} = -10868 J

data booklet -1367 kJ mol⁻¹

dift: ∴ incomplete transfer (to where?)

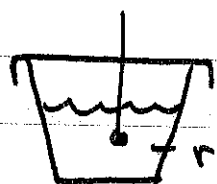
∴ incomplete combustion (low O₂)

∴ not std conditions

0.00976 moles = -113524.59 J mol⁻¹ = -113 kJ mol⁻¹ = -1100 kJ mol⁻¹ (sig fig)

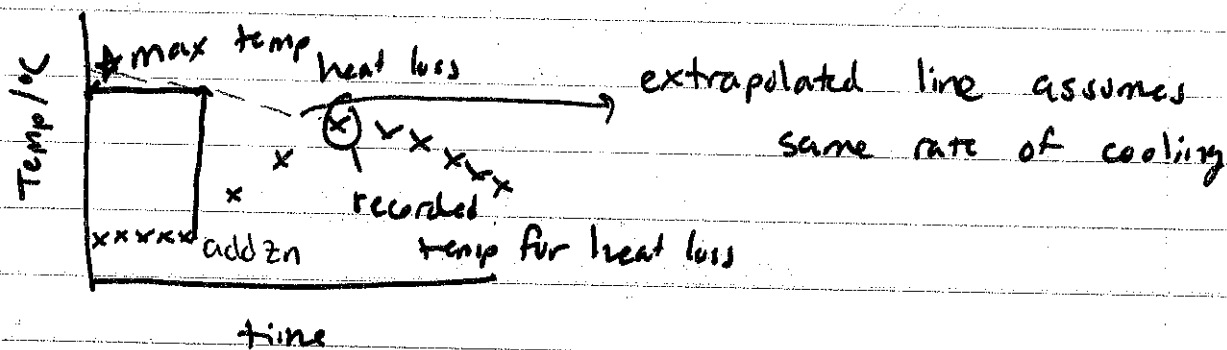
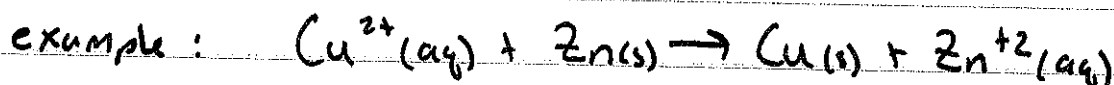
Enthalpy change Rxn in soln

- Carried out in a insulated system (polystyrene cup)
- Calculated by ΔT of H_2O



rxn occurs in soln ($T \downarrow$ or \uparrow)

insulating cup traps heat from surroundings



- Assumptions:
1. no heat loss from sys
 2. all heat transferred to H_2O
 3. dilute soln $V_{CuSO_4} = V_{H_2O}$
 4. H_2O density = 1.00 g cm^{-3}

$$\Delta H(\text{sys}) = 0$$

$$\Delta H(\text{sys}) = \Delta H_{(H_2O)} + \Delta H_{\text{rxn}}$$

$$\Delta H_{\text{rxn}} = -\Delta H_{H_2O}$$

$$\Delta H_{rxn} = - \frac{M_{H_2O} \times C_{H_2O} \times \Delta T_{H_2O}}{\text{mols of limiting reactant}}$$

↓ given conc. since in soln
or note what is in excess

* remember molarity

concentration = $\frac{\text{mols}}{\text{Volume (L)}}$

$$n_{CuSO_4} = [CuSO_4] \times \frac{V_{CuSO_4}}{1000} \leftarrow \begin{matrix} L \rightarrow ml \\ dm^3 \rightarrow cm^3 \end{matrix}$$

$$\Delta H_{rxn} = - \frac{M_{H_2O} \times C_{H_2O} \times \Delta T_{H_2O}}{n_{CuSO_4}} \quad J mol^{-1}$$

~~$\frac{M_{H_2O} \times C_{H_2O} \times \Delta T_{H_2O}}{[CuSO_4] \times \frac{V_{CuSO_4}}{1000}}$~~ assumption #3

~~$\frac{C_{H_2O} \times \Delta T_{H_2O}}{[CuSO_4] / 1000}$~~ $J mol^{-1}$

$$- \frac{C_{H_2O} \times \Delta T_{H_2O}}{[CuSO_4]} \quad kJ mol^{-1}$$

CuSO4:

conc: 1.00 mols dm³

ΔT: 20°C → 70°C

c: 4.18

$$\begin{aligned} & \frac{(4.18)(50)}{1.00} \\ & = -209 \text{ kJ mol}^{-1} \end{aligned}$$