ΔH is a conversion factor!

moles $\longleftrightarrow q_p$ ← heat, constant p.

ex:

$$\underline{\underline{2}}\,C_2H_6(g) + 7\,O_2(g) \longrightarrow 4\,CO_2(g) + 6\,H_2O(l)\ ;\ \Delta H = -5700\ \tfrac{kJ}{mol}$$

what's q_p is 12.5g of C_2H_6 react?

$\Delta H = -5700\ kJ/mol$ ← per mole of <u>RXN</u>

$-5700\ kJ = 2\ mol\ C_2H_6$

<u>C_2H_6</u>

$2 \times C = 2 \times 12.01$
$6 \times H = 6 \times 1.01$
30.08

$$\frac{12.5g\ C_2H_6}{} \left| \frac{1\ mol\ C_2H_6}{30.08g\ C_2H_6} \right| \frac{-5700\ kJ}{2 mol\ C_2H_6} = -1200\ kJ$$

MOLAR MASS; ΔH

exothermic → 1200 kJ of heat is RELEASED

Predicting ΔH of chemical rxns!

involves the use of <u>standard enthalpies of formation</u>.

ΔH_f°

° ← STD
- all gases are under a std. pressure of 1atm
- all soln's are at a std. conc. of 1M
- all solids + liquids are pure.

f ← formation

ΔH_f° of a substance is equal to ΔH for the reaction where we ~~make~~ form 1 mol of substance from its elements in their most stable forms.

ex: $\Delta H_f^\circ(C_6H_6(l)) = +49.04\ \frac{kJ}{mol}$

$6C(s,graphite) + 3H_2(g) \longrightarrow C_6H_6(l)\ ;\ \Delta H^\circ = +49.04\ \frac{kJ}{mol}$

Carbon exists in several forms .... Allotropes

$\boxed{C(s,graphite)}$, $C(s,diamond)$

$C(s,buckminsterfullerene)$, $C(s,bucky\ tubes)$

Oxygen exists in several forms...

$O_2(g)$ "oxygen" dioxygen

$O_3(g)$ ozone

ex: $\Delta H_f^\circ(CH_3OH(l)) = -238.7\ \frac{kJ}{mol}$

$C(s,graphite) + 2H_2(g) + \frac{1}{2}O_2(g) \longrightarrow CH_3OH(l)\ ;\ \Delta H^\circ = -238.7\ \frac{kJ}{mol}$

---

if we doubled up this rxn...

×2 ×2

$2C(s,graphite) + 4H_2(g) + O_2(g) \rightarrow 2CH_3OH(l)$

$\Delta H^\circ = -477.4\ \frac{kJ}{mol}$

There are tables in back of Chang that list hundreds of substances + their ΔH_f° values.

WHY? We can use them to predict ΔH for ANY chemical rxn.

Table 6.4 Standard Enthalpies of Formation of Some Inorganic Substances at 25°C

Substance	ΔH_f° (kJ/mol)	Substance	ΔH_f° (kJ/mol)
Ag(*s*)	0	$H_2O_2(l)$	−187.6
AgCl(*s*)	−127.04	Hg(*l*)	0
Al(*s*)	0	$I_2(s)$	0
$Al_2O_3(s)$	−1669.8	HI(*g*)	25.94
$Br_2(l)$	0	Mg(*s*)	0
HBr(*g*)	−36.2	MgO(*s*)	−601.8
C(graphite)	0	$MgCO_3(s)$	−1112.9
C(diamond)	1.90	$N_2(g)$	0
CO(*g*)	−110.5	$NH_3(g)$	−46.3
$CO_2(g)$	−393.5	NO(*g*)	90.4
Ca(*s*)	0	$NO_2(g)$	33.85
CaO(*s*)	−635.6	$N_2O_4(g)$	9.66
$CaCO_3(s)$	−1206.9	$N_2O(g)$	81.56
$Cl_2(g)$	0	O(*g*)	249.4
HCl(*g*)	−92.3	$O_2(g)$	0
Cu(*s*)	0	$O_3(g)$	142.2
CuO(*s*)	−155.2	S(rhombic)	0
$F_2(g)$	0	S(monoclinic)	0.30
HF(*g*)	−268.61	$SO_2(g)$	−296.1
H(*g*)	218.2	$SO_3(g)$	−395.2
$H_2(g)$	0	$H_2S(g)$	−20.15
$H_2O(g)$	−241.8	ZnO(*s*)	−347.98
$H_2O(l)$	−285.8	ZnS(*s*)	−202.9

†In thermodynamics, the standard pressure is defined as 1 bar, where 1 bar = 10^5 Pa = 0.987 atm. Because 1 bar differs from 1 atm by only 1.3 percent, we will continue to use 1 atm as the standard pressure. Note that the normal melting point and boiling point of a substance are defined in terms of 1 atm.

One little point...

$$\Delta H_f^\circ(\text{element in most stable form}) = 0 \ \frac{kJ}{mol}$$

ex: $\Delta H_f^\circ(O_2(g)) = 0$

WHY?

$$O_2(g) \longrightarrow O_2(g) \ ; \Delta H^\circ = 0$$

For any chemical rxn...

$$aA + bB \longrightarrow cC + dD$$

then $\Delta H^\circ = [c \times \Delta H_f^\circ(C) + d \times \Delta H_f^\circ(D)]$

$$\ominus \ [a \times \Delta H_f^\circ(A) + b \times \Delta H_f^\circ(B)]$$

OR $\Delta H^\circ = \underbrace{\sum}_{\text{sum}} \underbrace{n}_{\text{stoich. coefficients}} \cdot \Delta H_f^\circ(\text{Prods}) - \underbrace{\sum}_{\text{sum}} m \cdot \Delta H_f^\circ(\text{React})$

Reacts

ex: $12H_2(g) + C_6H_6(l) + 3O_2(g) \longrightarrow 6CH_3OH(l)$; ΔH° ?

given... $\Delta H_f^\circ(C_6H_6(l)) = +49.04\ kJ/mol$

$\Delta H_f^\circ(CH_3OH(l)) = -238.7\ kJ/mol$

then $\Delta H^\circ_{rxn} = \left[6 \times \Delta H_f^\circ(CH_3OH(l))\right]$

$\ominus \left[12 \times \cancel{\Delta H_f^\circ(H_2(g))}^{=0} + 1 \times \Delta H_f^\circ(C_6H_6(l)) \right.$
$\left. 3 \times \cancel{\Delta H_f^\circ(O_2(g))}^{=0}\right]$

$= \left[6 \times -238.7 \frac{kJ}{mol}\right] - \left[1 \times +49.04 \frac{kJ}{mol}\right]$

$= -1481.2\ kJ/mol$

ex: What's ΔH°_{rxn} for...

$N_2O_4(g) \longrightarrow 2NO_2(g)$

if $\Delta H_f^\circ(N_2O_4(g)) = +9.66\ kJ/mol$

if $\Delta H_f^\circ(NO_2(g)) = +33.85\ kJ/mol$

$\Rightarrow \Delta H^\circ_{rxn} = \left[2 \times \Delta H_f^\circ(NO_2(g))\right] - \left[1 \times \Delta H_f(N_2O_4(g))\right]$

$= \left(2 \times 33.85 \frac{kJ}{mol}\right) - \left(1 \times 9.66 \frac{kJ}{mol}\right)$

$= +58.0\ kJ/mol$

$\Delta(X) = X_{final} - X_{initial}$

$=$ Prods $-$ Reacts.

Calculate ΔH°_{rxn} for....

$$Al_2O_3(s) + 3CO(g) \longrightarrow 2Al(s) + 3CO_2(g)$$

if $\Delta H_f^\circ(Al_2O_3(s)) = -1669.8\ kJ/mol$

" $(CO(g)) = -110.5\ kJ/mol$

" $(CO_2(g)) = -393.5\ kJ/mol$

$$\Delta H^\circ_{rxn} = [2 \times \Delta H_f^\circ(Al(s)) + 3 \times \Delta H_f^\circ(CO_2(g))] - [1 \times \Delta H_f^\circ(Al_2O_3(s)) + 3 \times \Delta H_f^\circ(CO(g))]$$

$$= [2 \times 0 + 3 \times -393.5 \tfrac{kJ}{mol}] - [1 \times -1669.8 \tfrac{kJ}{mol} + 3 \times -110.5 \tfrac{kJ}{mol}]$$

$$= [-1180.5 \tfrac{kJ}{mol}] - [-2001.3 \tfrac{kJ}{mol}]$$

$$= +820.8\ kJ/mol$$ endothermic