

G = Gibbs free energy ...

$$\Delta G = \Delta H - T \Delta S$$

✓                      ↑                      ✓  
                                 measure                      easily calc.

$\Delta G = -ve$  , spontaneous      ●  
 $\Delta G = 0$  , @ eqm                      ●  
 $\Delta G = +ve$  , non-spontaneous      ●

$\Delta G = \text{max. amount of useful work}$   
 ↳ changes in FREE energy

Calculating  $\Delta G \dots$

$$(1) \Delta G = \Delta H - T \Delta S$$

↑                                      ↑  
 $\sum \Delta H_f^\circ (P) - (R)$

↑  
 $\sum S^\circ (P) - (R)$

(2) Can use standard Gibbs Energy of formation:  $\Delta G_f^\circ$

-  $\Delta G^\circ$  for the formation of 1 mol of cpd from its elements.

$$- \Delta G^\circ = \sum \Delta G_f^\circ (P) - (R)$$

p 642 ...

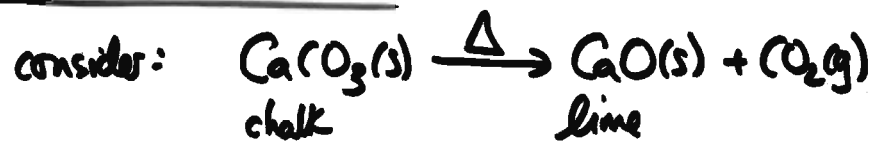
downside: STD conditions,  
1 atm, 1 M

- 25°C

Factors affecting the sign of  $\Delta G$

$\Delta H$	$\Delta S$	$\Delta G = \Delta H - T\Delta S$
+	+	+ve @ low T non-spont @ low T -ve @ high T spont @ high T
+	-	Always +ve, Non-spont @ all T
-	+	Always -ve, Spont @ all T
-	-	-ve @ low T Spont @ low T +ve @ high T non-spont @ high T

### Temp + Chem Reax



- does not occur @ 25°C.  $\Delta G = +ve$
- heat it up... eventually it occurs!  
 $\Delta G = -ve$

let's predict T where this rxn will be spont...  
 $\text{Ca}(\text{O}_3(\text{s})) \rightarrow \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$

Substance	$\text{Ca}(\text{O}_3(\text{s}))$	$\text{CaO}(\text{s})$	$\text{CO}_2(\text{g})$
$\Delta H_f^\circ$ (kJ/mol)	-1206.9	-635.6	-393.5
$S^\circ$ (J/mol.K)	92.9	39.8	213.6

$$\Delta S^\circ = \sum S^\circ(\text{P}) - (\text{R}) = +160.5 \text{ J/mol.K}$$

JUST DO IT ✓

$$\Delta H^\circ = \sum \Delta H_f^\circ(\text{P}) - (\text{R}) = +177.8 \frac{\text{kJ}}{\text{mol}}$$

JUST DO IT ✓

@ 25°C, 298K.

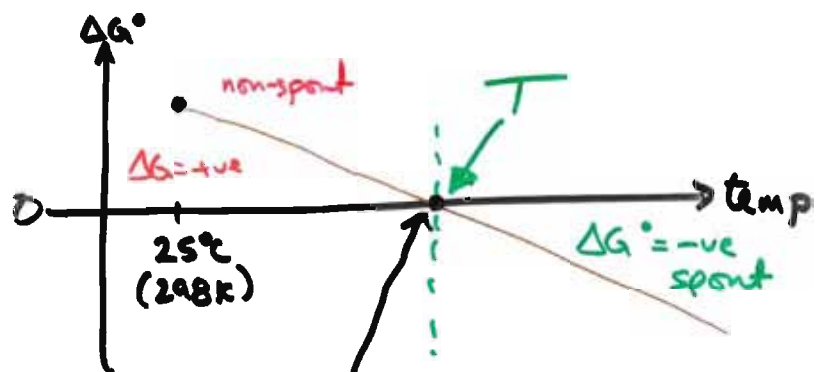
$$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ = +177,800 \frac{\text{J}}{\text{mol}} - 298\text{K} \times 160.5 \frac{\text{J}}{\text{mol.K}}$$

$\underbrace{\quad}_{+ve} \quad \underbrace{\quad}_{-ve}$

$$= 129,970 \text{ J/mol}$$

$$= +130. \text{ kJ/mol.}$$

⊙ non-spont.



let's solve for T

$$\Delta G^\circ = 0 = \Delta H^\circ - T\Delta S^\circ$$

$$\Rightarrow T\Delta S^\circ = \Delta H^\circ$$

$$\Rightarrow T = \frac{\Delta H^\circ}{\Delta S^\circ}$$

for our rxn...  $T = \frac{177,800 \text{ J/mol}}{160.5 \text{ J/mol}\cdot\text{K}} = 1108 \text{ K} = 835^\circ\text{C}$

$\Delta G^\circ$  vs  $\Delta G$

↑  
R/P are in  
STD conditions.

- 1 atm (g)  
1 M (solutions)  
pure (s, l)

↑  
whatever!  
- non-std conditions

Can show...

$$\Delta G = \Delta G^\circ + RT \ln Q$$

STD cond...  $Q = 1$  ( $C_j = 1 \text{ M}$ ,  $P = 1 \text{ atm}$ )

$$\ln(Q=1) = 0 \Rightarrow \Delta G = \Delta G^\circ$$

At eqm, ...  $Q = K$

$$\Delta G = 0$$

$$\Rightarrow 0 = \Delta G^\circ + RT \ln K$$

$$\Delta G^\circ = -RT \ln K$$

$$K = e^{-\frac{\Delta G^\circ}{RT}}$$

if  $K \gg 1$ ,  $\Delta G^\circ = -ve$

$$K \sim \frac{P}{R}$$

if  $K \ll 1$ ,  $\Delta G^\circ = +ve$

$$K \sim \frac{P}{R}$$

if  $K = 1$ ,  $\Delta G^\circ = 0$