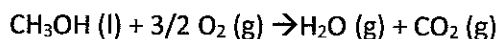


## Gibb's Free Energy

1. Methanol is used as a rocket fuel for the following chemical reaction:



- a) Predict the sign of  $\Delta S$  for the above reaction and explain your answer with sound reasoning.

$+\Delta S$  : # of gas particles increases  
 $1\frac{1}{2} \rightarrow 2$  particles

state change      liquid + gas  $\rightarrow$  gas  
(gas is more disordered)

- b) Predict the sign of  $\Delta H$  for the above reaction (knowing that it is combustion) and explain your answer with sound reasoning.

$-\Delta H$  : Combustion is exothermic

$\therefore \Delta H_{\text{products}} < \Delta H_{\text{reactants}}$

- c) Is the sign of  $\Delta G$  temperature dependent in this reaction? Explain your answer.

No - since enthalpy and entropy both agree that the reaction should happen, this reaction will be spontaneous at all temps.

2. Predict the signs for  $\Delta G$ ,  $\Delta H$  and  $\Delta S$  for the following situations and explain your answer.

- a) The vaporization of water above 100 °C.

$+\Delta S$  - increase in disorder as liquid  $\rightarrow$  gas

$+\Delta H$  - liquid has to absorb heat to become gas

$-\Delta G$  - vaporization is spontaneous at  $T > 100^\circ\text{C}$

- b) Does  $\Delta H$  or  $\Delta S$  favour the vaporization process?

$\Delta S$  favours vaporization  $\rightarrow$  increase in disorder

## Gibb's Free Energy

3. For the reaction  $\text{CO (g)} + \text{H}_2\text{O (g)} \rightarrow \text{CO}_2 \text{ (g)} + \text{H}_2 \text{ (g)}$

$$\Delta H = -41.2 \text{ kJ and } \Delta S = -135 \text{ J/K}$$

a) Calculate  $\Delta G$  at room temperature, 298 K.

$$\begin{aligned} \Delta G &= \Delta H - T\Delta S \\ \Delta G &= -41.2 \text{ kJ} - 298(-.135 \text{ kJ}) \\ \Delta G &= -0.97 \text{ kJ} \end{aligned}$$

b) Calculate  $\Delta G$  at 700K, assuming  $\Delta H$  and  $\Delta S$  are not affected by temperature.

$$\begin{aligned} \Delta G &= \Delta H - T\Delta S \\ \Delta G &= -41.2 \text{ kJ} - 700(-0.135) \\ \Delta G &= 53.3 \text{ kJ} \end{aligned}$$

c) Does raising the temperature favour this reaction, as written?

No - higher temp changes the reaction from spontaneous to non-spontaneous

d) Which factor, entropy or enthalpy, favours this reaction at high and low temperature?

Enthalpy  $\rightarrow$  it is negative (favourable)  
entropy is negative which isn't favourable.

4. Calculate the boiling point for the reaction:  $\text{BCl}_3 \text{ (l)} \rightarrow \text{BCl}_3 \text{ (g)}$

	$\Delta H^\circ$ (kJ/mol)	$\Delta S^\circ$ (J/mol-K)
$\text{BCl}_3 \text{ (l)}$ initial	-418	209
$\text{BCl}_3 \text{ (g)}$ final	-395	290

$$\Delta H = 23 \text{ kJ}$$

$$\Delta S = 81 \text{ J/mol K}$$

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

$$\rightarrow 0 = 23 - T(.081)$$

$$23 = T(.081)$$

$$T = 283.95 \text{ K} = \boxed{10.95^\circ\text{C}}$$

0 is the  
tipping point