

# ENTROPY & FREE ENERGY CALCULATIONS



Name ..... Form .....

substance	$S^\ominus$ ( $\text{J mol}^{-1} \text{K}^{-1}$ )	$\Delta H_f^\ominus$ ( $\text{kJ mol}^{-1}$ )
$\text{H}_2\text{O}(\text{g})$	189	-242
$\text{H}_2\text{O}(\text{l})$	70	
$\text{H}_2(\text{g})$	131	
$\text{Cl}_2(\text{g})$	223	
$\text{HCl}(\text{g})$	187	
$\text{NaHCO}_3(\text{s})$	102	-948
$\text{Na}_2\text{CO}_3(\text{s})$	136	-1131
$\text{C}_3\text{H}_8(\text{g})$	270	

substance	$S^\ominus$ ( $\text{J mol}^{-1} \text{K}^{-1}$ )	$\Delta H_f^\ominus$ ( $\text{kJ mol}^{-1}$ )
$\text{Fe}(\text{s})$	27	
$\text{O}_2(\text{g})$	205	
$\text{Fe}_2\text{O}_3(\text{s})$	90	-822
$\text{C}(\text{graphite})$	5.7	
$\text{CO}_2(\text{g})$	214	-394
$\text{N}_2(\text{g})$	192	
$\text{NH}_3(\text{g})$	193	

1) a) Predict the sign of  $\Delta S^\ominus$  for the following reactions, where possible, giving your reasoning for each one.

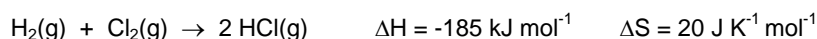
- i)  $\text{H}_2\text{O}(\text{g}) \rightarrow \text{H}_2\text{O}(\text{l})$
- ii)  $\text{H}_2(\text{g}) + \text{Cl}_2(\text{g}) \rightarrow 2 \text{HCl}(\text{g})$
- iii)  $\text{C}_3\text{H}_8(\text{g}) + 5 \text{O}_2(\text{g}) \rightarrow 3 \text{CO}_2(\text{g}) + 4 \text{H}_2\text{O}(\text{l})$

b) Calculate  $\Delta S^\ominus$  for the above reactions.

2) a) Sketch a graph to show how the entropy of water varies with temperature.

b) Show clearly the melting and boiling points on your graph.

3) a) Calculate  $\Delta G^\ominus$  for the following reaction at 298 K.



- b) Is this reaction feasible at 298 K?
- c) Why does this reaction not happen at room temperature?

4) For the decomposition:  $2 \text{NaHCO}_3(\text{s}) \rightarrow \text{Na}_2\text{CO}_3(\text{s}) + \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{g})$

- a) Calculate  $\Delta H^\ominus$  and  $\Delta S^\ominus$ .
- b) Calculate  $\Delta G^\ominus$  at 298 K.
- c) Calculate the temperature range over which the reaction is feasible.

5) Graphite burns in oxygen to form carbon dioxide.  $\text{C}(\text{graphite}) + \text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g})$

- a) Calculate  $\Delta S^\ominus$  at 298 K.
- b) Calculate  $\Delta G^\ominus$  at 298 K.

- 6) For the reaction:  $2 \text{Fe(s)} + \frac{3}{2} \text{O}_2\text{(g)} \rightarrow \text{Fe}_2\text{O}_3\text{(s)}$
- Calculate  $\Delta H^\ominus$  and  $\Delta S^\ominus$ .
  - Calculate  $\Delta G^\ominus$  at 298 K.
  - Calculate the temperature range over which the reaction is feasible.
- 7) a) Calculate  $\Delta S^\ominus$  for this reaction at 298 K:  $\text{Mg(s)} + \frac{1}{2} \text{O}_2\text{(g)} \rightarrow \text{MgO(s)}$   
 $\Delta H^\ominus = -602 \text{ kJ mol}^{-1}$   $\Delta G^\ominus = -570 \text{ kJ mol}^{-1}$
- Explain the sign and magnitude of  $\Delta S^\ominus$ .
- 8) a) Calculate  $\Delta H^\ominus$ ,  $\Delta S^\ominus$  and  $\Delta G^\ominus$  for the following reaction at 298 K:  
 $\text{Fe}_2\text{O}_3\text{(s)} + 3 \text{H}_2\text{(g)} \rightarrow 2 \text{Fe(s)} + 3 \text{H}_2\text{O(g)}$
- Will this reaction be feasible at 20°C?
  - Calculate the temperature range over which the reaction is feasible.
- 9) a) Calculate  $\Delta S^\ominus$  for the following process which takes place 91 K:  
 $\text{CH}_4\text{(s)} \rightarrow \text{CH}_4\text{(l)}$   $\Delta H^\ominus = 0.94 \text{ kJ mol}^{-1}$
- Calculate the boiling point of methane given:  
 $\text{CH}_4\text{(l)} \rightarrow \text{CH}_4\text{(g)}$   $\Delta H^\ominus = 8.2 \text{ kJ mol}^{-1}$   $\Delta S^\ominus = 73.2 \text{ J mol}^{-1} \text{K}^{-1}$
  - Compare the magnitude of the  $\Delta S$  values for melting and boiling methane and comment on the difference.
  - Explain why both melting and boiling are feasible at the temperatures shown, despite being endothermic.
- 10) The following enthalpy changes are at 298 K:  
 $\Delta H_{\text{hyd}}^\ominus$  (kJ mol<sup>-1</sup>):  $\text{K}^+$  -322;  $\text{Cl}^-$  -364      Lattice enthalpy KCl = -701 kJ mol<sup>-1</sup>
- Calculate the standard enthalpy of solution of potassium chloride at 298 K.
  - Potassium chloride dissolves readily in water at 298 K. Deduce the **sign** of the entropy change for this reaction, and explain your reasoning.
  - Explain, in terms of the behaviour of particles, why the entropy change has the sign given in your answer to (b).
  - Use your answer to (a) to calculate the smallest possible entropy change there must be when potassium chloride dissolves in water at 298 K, given that it is a feasible change.