

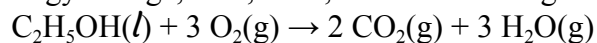
**Spontaneity and Gibbs free energy**

At 298K:

$$\Delta G_{rxn}^{\circ} = \sum n \Delta G_f^{\circ}(\text{products}) - \sum n \Delta G_f^{\circ}(\text{reactants})$$

At any temperature:

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

1. What is the standard free energy change,  $\Delta G^{\circ}$ , in kJ, for the following reaction at 298K?

Compound	$\Delta G_f^{\circ}$ (kJ/mol)
$\text{C}_2\text{H}_5\text{OH}(l)$	-175
$\text{CO}_2(g)$	-394
$\text{H}_2\text{O}(g)$	-229
$\text{O}_2(g)$	0

2. A reaction has a standard enthalpy change,  $\Delta H$ , of +10.00 kJ/mol at 298 K. The standard entropy change,  $\Delta S$ , for the same reaction is +10.00 J/mol·K. What is the value of  $\Delta G$  for the reaction in kJ/mol?

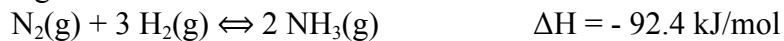
3. The equation for the decomposition of calcium carbonate is given below.



At 500 K,  $\Delta H$  for this reaction is +177 kJ/mol and  $\Delta S$  is 161 J/ mol·K

- a. Explain why  $\Delta H$  for the reaction above cannot be described as  $\Delta H_f^\circ$
  
  
  
  
  
  
  
  
  
  
- b. State the meaning of the term  $\Delta S$ .
  
  
  
  
  
  
  
  
  
  
- c. Calculate the value of  $\Delta G$  at 500 K and determine, giving a reason, whether the reaction will be spontaneous or not.

4. Consider the following reaction:



- a. The absolute entropy values,  $S$ , at 238 K for  $\text{N}_2(\text{g})$ ,  $\text{H}_2(\text{g})$  and  $\text{NH}_3(\text{g})$  are 192, 131 and 193 J/ mol·K respectively. Calculate  $\Delta S$  for the reaction and explain the sign of  $\Delta S$ .
  
  
  
  
  
  
  
  
  
  
- b. Calculate  $\Delta G$  for the reaction at 238 K. State and explain whether the reaction is spontaneous.

5. Hex-1-ene gas,  $C_6H_{12}$ , burns in oxygen to produce carbon dioxide and water vapor.

a. Write an equation to represent this reaction.

b. Use the data below to calculate the values of  $\Delta H^\circ$  and  $\Delta S^\circ$  for the combustion of hex-1-ene.

Substance	$O_2(g)$	$C_6H_{12}(g)$	$CO_2(g)$	$H_2O(g)$
Standard enthalpy of Formation, $\Delta H_f^\circ$ (kJ/mol)	0.0	-43	-394	-242
Entropy, $S^\circ$ (J/ mol·K)	205	385	214	189

i. Value of  $\Delta H_c^\circ$

ii. Value of  $\Delta S^\circ$

c. Calculate the standard free energy change for the combustion of hex-1-ene.

d. State and explain whether the combustion of hex-1-ene is spontaneous at  $25^\circ C$ .

e. At what temperature does this reaction become spontaneous?