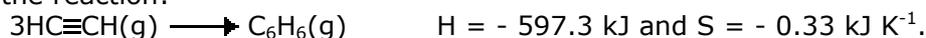


Exercise 4.63 – Gibbs free energy calculations

Q463-01 For the reaction:



This reaction:

- A. is spontaneous at 300 K and becomes non-spontaneous at higher temperatures.
- B. is spontaneous at 300 K and becomes non-spontaneous at lower temperatures.
- C. is non-spontaneous at 300 K and becomes spontaneous at higher temperatures.
- D. is non-spontaneous at 300 K and becomes spontaneous at lower temperatures.

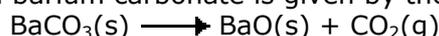
Q463-02 For the process:



$$\Delta H^\ominus = -9.83 \text{ kJmol}^{-1} \text{ and } \Delta S^\ominus = -35.2 \text{ J K}^{-1} \text{ mol}^{-1}.$$

- a) Predict and explain the effect of an increase in temperature of the spontaneity of the process.
- b) Calculate the temperature (in °C) at which $\Delta G = 0$ for the above process and explain the significance of this temperature.

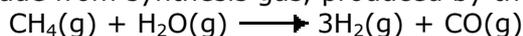
Q463-03 Decomposition of solid barium carbonate is given by the following equation:



compound	BaCO ₃ (s)	CO ₂ (g)	BaO(s)
$\Delta H_f^\ominus / \text{kJmol}^{-1}$	-1219	-394	-558
$S^\ominus / \text{JK}^{-1} \text{ mol}^{-1}$	+112	+214	+70

- a) Calculate the value of ΔG^\ominus in kJ mol^{-1} at 25°C
- b) State with a reason whether the reaction is spontaneous at 25°C
- c) Determine the minimum temperature above which the reaction is spontaneous.

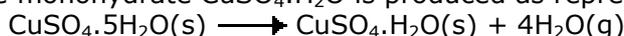
Q463-04 Methanol can be made from synthesis gas, produced by the reaction:



For this reaction $\Delta H^\ominus = +210 \text{ kJ}$ and $\Delta S^\ominus = 216 \text{ JK}^{-1}$

- a) Use these values to explain why this reaction is not spontaneous at 298K.
- b) Calculate the temperature at which it becomes spontaneous.

Q463-05 When solid blue copper (II) sulphate pentahydrate $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ loses water, the white solid copper (II) sulphate monohydrate $\text{CuSO}_4 \cdot \text{H}_2\text{O}$ is produced as represented by the equation:



The thermodynamic data for the substances involved in the reversible process are:

	$\Delta H_f^\ominus / \text{kJmol}^{-1}$	$S^\ominus / \text{J K}^{-1} \text{ mol}^{-1}$
$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}(\text{s})$	-2278	305
$\text{CuSO}_4 \cdot \text{H}_2\text{O}(\text{s})$	-1084	150
$\text{H}_2\text{O}(\text{g})$	-242	189

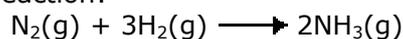
- a) Calculate the value of ΔH^\ominus for the reaction above and state what information the sign of ΔH^\ominus provides about this reaction.
- b) Calculate ΔS^\ominus for the reaction and state the meaning of the sign of ΔS^\ominus obtained.
- c) Identify a thermodynamic function that can be used to predict the reaction spontaneity and state its units.
- d) Use the values obtained in the above to determine whether the reaction is spontaneous or non-spontaneous at 25°C.

Exercise 4.63 – Gibbs free energy calculations

Q463-06 Using the answers in question 7 above:

- identify which compound $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}(\text{s})$, or $\text{CuSO}_4 \cdot \text{H}_2\text{O}(\text{s})$ is more stable at 25°C
- Use the values obtained in question 7 to determine the centigrade temperature above which the other compound is more stable.

Q463-07 Consider the following reaction:



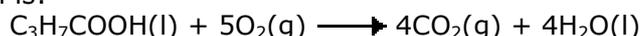
- Using average bond enthalpies values below, calculate the standard enthalpy change for this reaction.

Bond enthalpies (kJ mol^{-1}): $\text{N}\equiv\text{N}$, 942; $\text{H}-\text{H}$, 432; $\text{N}-\text{H}$, 386.

The absolute entropy values, S , at 300K for $\text{N}_2(\text{g})$, $\text{H}_2(\text{g})$ and $\text{NH}_3(\text{g})$ are 193, 131 and $192 \text{ J K}^{-1} \text{ mol}^{-1}$ respectively.

- Calculate ΔS^\ominus for the reaction and explain the sign of ΔS^\ominus
- Calculate ΔG^\ominus for the reaction at 300K.

Q463-08 The enthalpy change for the combustion of butanoic acid at 25°C is $-2183.5 \text{ kJ mol}^{-1}$. The combustion reaction is:

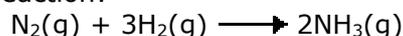


- Write the balanced equation for the formation of butanoic acid from its elements.
- Using the data below, calculate the standard enthalpy of formation, H^\ominus_f , for butanoic acid.

Substance	Standard Enthalpy of Formation, $H^\ominus_f / \text{kJ mol}^{-1}$	Absolute Entropy, S , / $\text{J mol}^{-1} \text{K}^{-1}$
$\text{C}(\text{s})$	0	5.7
$\text{CO}_2(\text{g})$	-393.5	213.6
$\text{H}_2(\text{g})$	0	130.6
$\text{H}_2\text{O}(\text{l})$	-285.9	60.9
$\text{O}_2(\text{g})$	0	205.0
$\text{C}_3\text{H}_7\text{COOH}(\text{l})$		226.3

- Calculate the standard entropy change, S^\ominus_f , for the formation of butanoic acid at 25°C
- Calculate the standard free energy of formation, G^\ominus_f , for butanoic acid at 25°C
- Is this reaction spontaneous at 25°C ? Explain your answer

Q463-09 Consider the following reaction:



The enthalpy change, ΔH^\ominus for this reaction = -92 kJ . The magnitude of the entropy change ΔS , at 27°C for the reaction is $-202 \text{ J K}^{-1} \text{ mol}^{-1}$. Calculate ΔG for this reaction at 27°C and determine whether this reaction is spontaneous at this temperature.

Q463-10 The equation for the decomposition of calcium carbonate is given below:



At 500K , ΔH for this reaction is $+177 \text{ kJ mol}^{-1}$ and ΔS is $161 \text{ J K}^{-1} \text{ mol}^{-1}$. Calculate the value of ΔG at 500K and determine, giving a reason, whether or not the reaction is spontaneous.