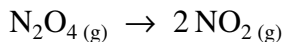


Problems of Thermochemistry: Gibbs free energy and spontaneity

1) Consider the following reaction:

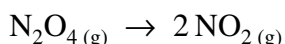


The standard enthalpy of this reaction is 57.2 kJ and its standard entropy is 175.61 J/K.

Find out:

- The change of the Gibbs free energy at 25 °C. Is the reaction spontaneous at 25 °C?
- The temperature where the spontaneity of the reaction changes assuming that the enthalpy and the entropy are constant.

2) Given the reaction:



Find out:

- The change of enthalpy at 25 °C.
- The change of entropy at 25 °C.
- The change of the Gibbs free energy at 25 °C. Is the reaction spontaneous at 25 °C?
- The temperature where the spontaneity of the reaction changes assuming that the enthalpy and the entropy are constant.

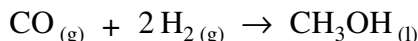
Enthalpies of formation (in kJ/mol at 25 °C, 1 atm):

$$\Delta H_f^\circ(\text{N}_2\text{O}_4(\text{g})) = 9.16, \quad \Delta H_f^\circ(\text{NO}_2(\text{g})) = 33.18$$

Standard entropies (in J/(mol·K) at 25 °C and 1 atm):

$$S^\circ(\text{N}_2\text{O}_4(\text{g})) = 304.29, \quad S^\circ(\text{NO}_2(\text{g})) = 239.95$$

3) Consider the reaction:



The standard enthalpy of this reaction is -128.13 kJ and its standard entropy is -332.5 J/K.

Determine:

- The change in the Gibbs free energy at 25 °C.
- The change in the Gibbs free energy at 794 °C assuming that the enthalpy and the entropy do not change at this temperature.

Problems of Thermochemistry: Gibbs free energy and spontaneity

4) Consider the following reaction:



Calculate:

- The change of enthalpy at 25 °C.
- The change of entropy at 25 °C.
- The change in the Gibbs free energy at 25 °C.
- The change in the Gibbs free energy at 639 °C assuming that the enthalpy and the entropy do not change at this temperature.

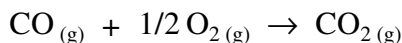
Enthalpies of formation (in kJ/mol at 25 °C, 1 atm):

$$\Delta H_f^\circ(\text{PCl}_5(\text{g})) = -374.9, \quad \Delta H_f^\circ(\text{PCl}_3(\text{g})) = -287$$

Standard entropies (in J/(mol·K) at 25 °C and 1 atm):

$$S^\circ(\text{PCl}_5(\text{g})) = 364.58, \quad S^\circ(\text{PCl}_3(\text{g})) = 311.78, \quad S^\circ(\text{Cl}_2(\text{g})) = 223.07$$

5) Consider the reaction:

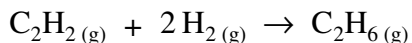


The standard enthalpy of this reaction is -282.98 kJ and its standard entropy is -86.82 J/K.

Find out:

- The change of the Gibbs free energy at 25 °C. Is the reaction spontaneous at 25 °C?
- The temperature where the spontaneity of the reaction changes assuming that the enthalpy and the entropy are constant.

6) Given the reaction:



Find out:

- The change of enthalpy at 25 °C.
- The change of entropy at 25 °C.
- The change of the Gibbs free energy at 25 °C. Is the reaction spontaneous at 25 °C?
- The temperature where the spontaneity of the reaction changes assuming that the enthalpy and the entropy are constant.

Enthalpies of formation (in kJ/mol at 25 °C, 1 atm):

$$\Delta H_f^\circ(\text{C}_2\text{H}_2(\text{g})) = 227.48, \quad \Delta H_f^\circ(\text{C}_2\text{H}_6(\text{g})) = -83.85$$

Standard entropies (in J/(mol·K) at 25 °C and 1 atm):

$$S^\circ(\text{C}_2\text{H}_2(\text{g})) = 200.82, \quad S^\circ(\text{H}_2(\text{g})) = 130.7, \quad S^\circ(\text{C}_2\text{H}_6(\text{g})) = 229.49$$

Problems of Thermochemistry: Gibbs free energy and spontaneity

7) Consider the following reaction:

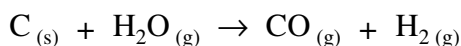


The standard enthalpy of this reaction is 42.05 kJ and its standard entropy is -18.28 J/K .

Find out:

- a) The change in the Gibbs free energy at 25°C .
- b) The change in the Gibbs free energy at 169°C assuming that the enthalpy and the entropy do not change at this temperature.

8) Consider the following reaction:



Find out:

- a) The change of enthalpy at 25°C .
- b) The change of entropy at 25°C .
- c) The change in the Gibbs free energy at 25°C .
- d) The change in the Gibbs free energy at 529°C assuming that the enthalpy and the entropy do not change at this temperature.

Enthalpies of formation (in kJ/mol at 25°C , 1 atm):

$$\Delta H_f^\circ(\text{H}_2\text{O}_{(\text{g})}) = -241.82, \quad \Delta H_f^\circ(\text{CO}_{(\text{g})}) = -110.53$$

Standard entropies (in J/(mol·K) at 25°C and 1 atm):

$$S^\circ(\text{C}_{(\text{s})}) = 5.74, \quad S^\circ(\text{H}_2\text{O}_{(\text{g})}) = 188.8, \quad S^\circ(\text{CO}_{(\text{g})}) = 197.9, \quad S^\circ(\text{H}_{2(\text{g})}) = 130.7$$

Answers:

- 1) a) 4.84 kJ (non-spontaneous), b) 52.57°C .
- 2) a) 57.2 kJ, b) 175.61 J/K, c) 4.84 kJ (non-spontaneous), d) 52.57°C .
- 3) a) -29 kJ , b) 226.7 kJ.
- 4) a) 87.9 kJ, b) 170.27 J/K, c) 37.13 kJ, d) -67.41 kJ .
- 5) a) -257.09 kJ (spontaneous), b) 2986°C .
- 6) a) -311.33 kJ , b) -232.73 J/K , c) -241.94 kJ (spontaneous), d) 1065°C .
- 7) a) 47.5 kJ, b) 50.13 kJ.
- 8) a) 131.29 kJ, b) 134.06 J/K, c) 91.32 kJ, d) 23.75 kJ.