General Certificate of Education (Advanced Level) Examination

Chemistry

Gibbs free Energy

(Worksheet)

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This worksheet tests your understanding of Gibbs free energy, spontaneity of reactions, and the relationship between enthalpy, entropy, and temperature.

Section A: Conceptual Questions

1. Define Gibbs free energy (G).

2. Write the equation relating Gibbs free energy change, enthalpy change, and entropy change.

3. What is meant by a spontaneous process?

4. State the condition for a reaction to be spontaneous in terms of ΔG.

5. Explain why some reactions become spontaneous only at high temperatures.

Section B: Multiple Choice Questions

1. A reaction is spontaneous when ΔG is:
   (a) Positive
   (b) Zero
   (c) Negative
   (d) Maximum

2. For an endothermic reaction with an increase in entropy, the reaction is spontaneous:
   (a) At all temperatures
   (b) At low temperatures
   (c) At high temperatures
   (d) Never

3. If $\Delta H < 0$ and $\Delta S < 0$, the reaction is spontaneous:
   (a) At high temperatures
   (b) At low temperatures
   (c) At all temperatures
   (d) At no temperature

Section C: Structured Questions

1. Calculate the Gibbs free energy change at 298 K for a reaction with $\Delta H = -120$ kJ mol^{-1} and $\Delta S = -250$ J K^{-1} mol^{-1}. State whether the reaction is spontaneous.

2. For a reaction, $\Delta H = +85$ kJ mol^{-1} and $\Delta S = +200$ J K^{-1} mol^{-1}.
   (a) Calculate ΔG at 300 K.

   (b) Determine the minimum temperature at which the reaction becomes spontaneous.

Section A:

1. Gibbs free energy is the thermodynamic quantity that indicates the maximum useful work obtainable from a system at constant temperature and pressure.
2. $\Delta G = \Delta H - T\Delta S$
3. A spontaneous process is one that occurs naturally under given conditions without an external intervention.
4. A reaction is spontaneous when $\Delta G < 0$.
5. For reactions where ΔH is positive and ΔS is positive, the $T\Delta S$ term increases with temperature. At sufficiently high temperature, $T\Delta S > \Delta H$, making ΔG negative and the reaction spontaneous.

Section B:

1. (c) Negative
2. (c) At high temperatures
3. (b) At low temperatures

C: Structured Questions

1. Equation: $\Delta G = \Delta H - T\Delta S$

   $\Delta G = -120 \text{ kJ mol}^{-1} - [298 \text{ K} \times (-0.250) \text{ kJ mol}^{-1} \text{ K}^{-1}]$

   $= -45.5 \text{ kJ mol}^{-1}$

   As ΔG is negative, the reaction is spontaneous at 298 K.

2. (a) $\Delta G = \Delta H - T\Delta S$

   $\Delta G = 85 \text{ kJ mol}^{-1} - (300 \text{ K} \times 0.200 \text{ kJ mol}^{-1} \text{ K}^{-1})$

   $= +25 \text{ kJ mol}^{-1}$

   As ΔG is positive, the reaction is not spontaneous at 300 K.

   (b) For spontaneity: $\Delta G < 0$

   So, $\Delta H - T\Delta S < 0$

   $85 \text{ kJ mol}^{-1} - (T \times 0.200 \text{ kJ mol}^{-1} \text{ K}^{-1}) < 0$

   $85 \text{ kJ mol}^{-1} < T \times 0.200 \text{ kJ mol}^{-1} \text{ K}^{-1}$

   $\frac{85}{0.2} \text{ K} < T$

   $425 \text{ K} < T$

   The reaction becomes spontaneous at temperatures above 425 K.