Electrochemistry – Calculating Gibbs Free Energy

Given Data:

Redox Reaction: Fe^{2+} (aq) + HNO_2 (aq) + H^+ (aq) → Fe^{3+} (aq) + NO (aq) + H_2O (l)

Step 1: Determine the half-reactions and their standard reduction potentials (E°) from standard tables.

1. Reduction half-reaction:
   Fe^{3+} (aq) + e^- → Fe^{2+} (aq); $E^\circ(Fe^{3+}/Fe^{2+}) = +0.77$ V
2. Oxidation half-reaction:
   HNO_2 (aq) + H^+ (aq) + e^- → NO (g) + H_2O (l); $E^\circ(HNO_2/NO) = +0.994$ V

Explanation: This step involves finding the standard reduction potentials (E°) for the involved half-reactions from a standard table.

Supporting Statement: To calculate Gibbs Free Energy change, the standard reduction potentials for each half-reaction must be identified from standard tables or verified sources.

Step 2: Determine the overall standard cell potential (E°cell).

$E^\circ_{cell} = E^\circ_{cathode} - E^\circ_{anode}$
Given:
$E^\circ_{cathode} = +0.77$ V
$E^\circ_{anode} = +0.994$ V
$E^\circ_{cell} = 0.77 \text{ V} - 0.994 \text{ V} = -0.224$ V

Explanation: The standard cell potential (E°cell) is calculated by subtracting the anode potential from the cathode potential. This reflects the overall potential difference driving the redox reaction.

Supporting Statement: Using the given standard reduction potentials, the overall cell potential can be calculated to proceed with Gibbs Free Energy calculations.

Step 3: Calculate the standard free energy change (ΔG°).

Using the formula:
$\Delta G^\circ = -nFE^\circ_{cell}$
Where:
- n = number of moles of electrons transferred (1 mol here, as only one electron is involved in both half-reactions)
- F = Faraday's constant (96485 C/mol)
- E°_{cell} = standard cell potential

Substitute the values:
$\Delta G^\circ = -(1 \text{ mol}) \times (96485 \text{ C/mol}) \times (-0.224 \text{ V})$
$\Delta G^\circ = 21612.64$ J/mol

Explanation: The standard free energy change (ΔG°) is determined using the relationship ΔG° = -nFE°cell. This indicates the thermodynamic favorability of the reaction.

Supporting Statement: The equation for Gibbs Free Energy relies on the number of moles of electrons transferred, Faraday's constant, and the standard cell potential.

Final Step: Report the final answer with appropriate significant digits.

$\Delta G^\circ \approx 21612$ J/mol

Explanation: The final value is adjusted to the appropriate significant digits considering the precision of given constants and measured values.

Supporting Statement: Ensure the final result is presented with correct significant figures based on input data precision.

Final Solution:

The standard reaction free energy (ΔG°) for the given redox reaction is approximately 21612 J/mol.