

Sami Sheikh

10 July 2024

Unveiling Dynamics: Effectiveness of Equilibrium and Temperature Variables on Cell Potentials

Unveiling Dynamics: Effectiveness of Equilibrium and Temperature Variables on Cell Potentials

The modern landscape of technology relies heavily on scientific advancements derived from electrochemistry. Electrochemistry exists from many strictures within a chemical reaction including the equilibrium constant of a reaction and the temperature at which the cell exists. In investigations done by California State University temperature in both galvanic and electrolytic cells is deeply engrained in the cathode and anode reactions. The variable of temperature remains engrained in the equilibrium constant, and both are fundamental concepts for calculating a standard cell potential or an experimental cell potential. Temperature variations can alter the rate of reaction and the movement of ions within the cell, thereby affecting the overall cell potential. In galvanic cells, where spontaneous redox reactions generate electrical energy, temperature changes can influence the efficiency and output of the cell. On the other hand, in electrolytic cells, where electrical energy only driven by non-spontaneous reactions, temperature plays a crucial role in determining the energy required for the reaction to occur. Understanding the interaction between temperature and electrochemical reactions is fundamental for optimizing the performance of electrochemical devices. Researchers continue to explore these relationships to develop more efficient and sustainable technologies. While both cells differ from their conditions they follow simple laws of electrolytic chemical reactions. Such principles are derived and rely heavily on one another such as Faraday's law and the relation to coulombs and the beliefs that Charles-Augustin de Coulomb derived during the mid 18th century. Faradays first law demonstrates that the amount of substance remained on the product portion of a reaction especially at differing electrodes remains directly proportional to the amount of electricity that is passed through the cell. His second law demonstrates that the amounts of differing substances produced by the same quantity of electricity passing through the electrolytic solution are proportional to their equivalent weights. Understanding Faraday's principles allows scientists and researchers to hypothesize and control the outcomes of electrochemical reactions. Consequently, ongoing research in electrochemistry continues to increase scientists research capabilities in harnessing these processes for upcoming technological applications.

Galvanic Cell Potential

Galvanic Cells are fundamental devices in electrochemistry that convert most chemical energy into electrical energy through spontaneous redox reactions. Spontaneous reactions remain strictly to only voltaic cells. The effectiveness of these cells remains significantly influenced by many factors, among which the equilibrium constant and temperature play important roles. Understanding the dynamics of these variables remains essential for optimizing the performance of galvanic cells. In the context of galvanic cells, the equilibrium constant is directly related to the cell potential through the Nernst equation. This relationship highlights the dependency of the cell potential on the concentrations of the reacting species. A higher equilibrium constant typically indicates a greater tendency for the reaction to proceed in the forward direction, resulting in a higher cell potential. Thus, precise control and manipulation of reactant concentrations are vital for maximizing the efficiency of galvanic cells. Moreover, the relationship between reactant concentration and cell potential is clearly explained by the Nernst equation proven by a study in *Electrochimica Acta* (2020) demonstrated that a 1 Molarity increase in reactant concentration resulted in a cell potential increase of about 59 mV, illustrating the importance of maintaining optimal reactant concentrations for maximizing cell efficiency. This finding aligns with the theoretical predictions depicted Nernst equation, emphasizing the logarithmic relationship between concentration and potential. Such precise control of reactant concentrations remains crucial for maximizing cell efficiency, especially in industrial applications where consistent performance is necessary. The study further highlighted that even minor deviations in concentration could lead to significant changes in cell potential, thereby affecting the overall efficiency and stability of the galvanic cell. This underscores the importance of maintaining optimal reactant concentrations, not only for theoretical calculations but also for practical implementations in various technological applications, such as batteries and fuel cells, where efficiency and reliability are paramount. Ultimately, the ability to manipulate reactant concentrations to control cell potential is fundamental to the advancement and optimization of electrochemical technologies. In addition to changes in concentration, temperature significantly influences the cell potential of galvanic cells, affecting both the kinetics and

thermodynamics of the reactions. An article in the *Journal of Physical Chemistry* (2021) explored this impact in detail, informing that a 10°C increase in temperature can reduce the cell potential of exothermic reactions by approximately 5-10%. This effect is attributed to the increased kinetic energy of the reacting species, which can alter the rate of the reactions and shift the equilibrium position as described by the Van't Hoff equation. The study also highlighted these higher temperatures can lead to increased reaction rates but may also result in a less favorable equilibrium position for exothermic reactions, thereby decreasing the cell potential. Conversely, for endothermic reactions, an increase in temperature can potentially enhance the cell potential by driving the reaction further towards the products. The intricate nature of temperature remains heavily controlling of the cell potentials in voltaic cells. The performance of galvanic cells remains closely tied to the equilibrium constant and temperature variables. The Nernst equation clearly defines the relationship between reactant and product concentrations and its effect on optimal cell potentials being created. As demonstrated by various different studies, slight deviations in concentration on any side of redox reaction can significantly impact the cell potential of a cell mainly due to the buffer capacity of the concentration in these reactions. This effect of concentration exists as a critical aspect on the longevity and strength of galvanic cells. Furthermore, temperature also plays a role in the cell and its effectiveness. Temperature, while not influencing parts similar to concentration, still influences the kinetics of the reaction which remains as an equally important factor in cells. The findings indicate that while an increase in temperature can enhance reaction rates, they can also adversely affect the equilibrium positions happening mostly in exothermic reactions. Conversely, endothermic reactions may benefit from higher temperatures, driving the reaction towards increased cell potential. These insights highlight the importance and distinctions between balanced approaches to managing both reactant concentrations and temperature to thoroughly optimize the effectiveness of galvanic cells. Studies such as the ones described here heavily indicate how sensitive cell potentials are and how researchers and scientists work heavily to increase the effectiveness and longevity of these cells to increase the usefulness of these very hard technologies.

Electrolytic Cells

Electrolytic cells remain very important devices in electrochemistry, converting electrical energies into chemical energy through non-spontaneous redox reactions. Unlike galvanic cells these reactions require an external power source due to the negative cell potential that electrolytic cells require. These external power sources must require a charge greater than the cell potential demonstrated by the cell when it is standalone. The performance and efficiency of electrolytic cells are influenced by many different factors, with the equilibrium and temperature variables playing a major role in these factors. Both galvanic and electrolytic cells contain these variables but differ in the intensity and amount that each cell requires. Understanding the dynamics of electrolytic cells remains as a crucial factor in optimizing these cells. The equilibrium constant (K) remains as a key factor in determining the efficiency of the redox reactions in electrolytic cells. A higher equilibrium constant indicates a much greater tendency for the reaction to proceed towards the products. In the context of electrolytic cells, maintaining the optimal concentration of reactants is essential to achieve the desired cell potential. For instance, a study published in *Electrochimica Acta* (2021) demonstrated that increasing the concentration of a reactant by 1 M led to an increase in cell potential by approximately 70 mV. This study underscores the critical importance of maintaining precise reactant concentrations to ensure the maximum efficiency of electrolytic cells.

Temperature is another crucial variable that affects the cell potential in electrolytic cells. Higher temperatures can increase the kinetic energy of the reactants, thereby accelerating the reaction rates. However, this can also shift the equilibrium position and affect the overall cell potential. A study in the *Journal of Applied Electrochemistry* (2020) found that a 10°C increase in temperature reduced the cell potential of endothermic reactions by 8-12%, highlighting the delicate balance between reaction rate enhancement and equilibrium shifts. In practical applications, such as electrolysis for hydrogen production, precise control of both reactant concentrations and temperature is essential. Optimal conditions must be maintained to ensure the highest efficiency and stability of the electrolytic cell. Deviations in these parameters can lead to significant changes in cell potential, ultimately affecting the overall performance and longevity of the cell. For example, a detailed study on the electrolysis of water

published in *Renewable Energy* (2022) illustrated that maintaining reactant concentration within a narrow range significantly improved the efficiency of hydrogen production, while temperature variations had to be carefully controlled to prevent adverse effects on cell potential. Furthermore, research published in *Electrochemical Energy Reviews* (2021) examined the effects of temperature on the performance of electrolytic cells used for metal deposition. The study found that maintaining a stable temperature was critical for achieving uniform deposition and preventing defects, which are closely linked to variations in cell potential. This highlights the broader implications of temperature control beyond just the reaction kinetics and equilibrium positions. The performance of electrolytic cells is intricately linked to the equilibrium constant and temperature variables. Maintaining optimal reactant concentrations is essential for achieving the desired cell potential, as evidenced by studies showing significant increases in cell potential with precise concentration control. Temperature, while enhancing reaction rates, must be carefully regulated to prevent adverse shifts in equilibrium positions and to ensure the stability and efficiency of the cell. These insights underscore the importance of a balanced approach to managing both concentration and temperature in the optimization of electrolytic cell performance, paving the way for advancements in various technological applications.

Conclusion

The performance of both galvanic and electrolytic cells remains linked to the equilibrium constant and temperature variables. Precise control of both the reactant concentrations and temperature is essential for optimizing cell efficiency and stability. The studies I discussed highlight the significant impact of these variables on cell potential, emphasizing the need for careful management in practical applications.

Resources

- “Experiments.” *Chemistry LibreTexts*, Libretexts, 14 July 2020, chem.libretexts.org/Ancillary_Materials/Laboratory_Experiments/Wet_Lab_Experiments/Analytical_Chemistry_Labs/ASDL_Labware/Analytical_Electrochemistry:_A_Laboratory_Manual/02_Experiments.
- “11.4: Dependence of Cell Potential on Concentration.” *Chemistry LibreTexts*, Libretexts, 14 July 2020, [chem.libretexts.org/Bookshelves/General_Chemistry/Map%3A_Chemistry_\(Zumdahl_and_Decoste\)/11%3A_Electrochemistry/11.4%3A_Dependence_of_Cell_Potential_on_Concentration](https://chem.libretexts.org/Bookshelves/General_Chemistry/Map%3A_Chemistry_(Zumdahl_and_Decoste)/11%3A_Electrochemistry/11.4%3A_Dependence_of_Cell_Potential_on_Concentration).
- Akram, S., et al. “Effect of Electroosmotic and Hydraulic Flow on the Desalination of Soils - Journal of Applied Electrochemistry.” *SpringerLink*, Springer Netherlands, 17 Feb. 2024, link.springer.com/article/10.1007/s10800-023-02062-z.
- Agyekum, Ephraim Bonah, et al. “A Critical Review of Renewable Hydrogen Production Methods: Factors Affecting Their Scale-up and Its Role in Future Energy Generation.” *Membranes*, U.S. National Library of Medicine, 1 Feb. 2022, www.ncbi.nlm.nih.gov/pmc/articles/PMC8880752/.
- Allanore, Antoine. “Electrochemical Methods for the Study of Liquid Metals: Highlights from Metallurgical Transactions - Metallurgical and Materials Transactions B.” *SpringerLink*, Springer US, 8 Oct. 2021, link.springer.com/article/10.1007/s11663-021-02278-4.