Work through the ChemCAL modules “Reaction Rates and Chemical Kinetics 1” and “Reaction Rates and Chemical Kinetics 2”

1. Nicotinamide adenine dinucleotide (NADH), a cofactor in many biochemical reactions, is a strong reducing agent in water solution:

\[ \text{NADH} + \text{H}^+ \rightleftharpoons \text{NAD}^+ + 2\text{H}^+ + 2\text{e}^- \quad E^\circ = 0.527 \text{ V} \]

Calculate the value of \( E^\circ \) (reduction potential at the biological standard state of pH = 7.0) for this half cell at 298 K.

2. The pyruvate ion (Pv\(^-\)) is reduced to the lactate ion (PvH\(_2\)^-) at pH 7 in half cell below.

\[ \text{Pv}^- + 2\text{H}^+ + 2\text{e}^- \rightleftharpoons \text{PvH}_2^- \quad E^\circ' = -0.185 \text{ V} \]

Assume this half cell is combined with the NAD ion half cell of Q1 at pH 7.

(a) What is the overall cell reaction?
(b) What is the voltage of this cell at pH 7?
(c) What is the equilibrium constant for this reaction at 298 K and pH 7?
(d) What is the value of \( \Delta G^\circ \) for this reaction at 298 K?
(e) Would the EMF of the cell increase, decrease or remain unchanged if:
   (i) the pH were reduced to 6.0? and (ii) [NADH] were reduced to 0.1 M?

3. Typical concentrations of Na\(^+\) and K\(^+\) in the intracellular and extracellular fluid are given below. Assuming that cell membrane has a much higher permeability to K\(^+\) than all other ions, estimate the potential difference between the inside and the outside of the cell.

\[
\begin{align*}
[\text{Na}^+] & : 142 \text{ mM extracellular, } 10 \text{ mM intracellular} \\
[\text{K}^+] & : 4 \text{ mM extracellular, } 140 \text{ mM intracellular}
\end{align*}
\]

4. One of the key reactions in the formation of acid rain and in the industrial production of nitric acid is the reaction of nitric oxide with oxygen:

\[ \text{O}_2(\text{g}) + 2\text{NO}(\text{g}) \rightarrow 2\text{NO}_2(\text{g}) \]

The following data were obtained at constant temperature.

<table>
<thead>
<tr>
<th>experiment number</th>
<th>initial concentrations (mol L(^{-1}))</th>
<th>initial reaction rate (mol L(^{-1}) s(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>(1.10 \times 10^{-2}) (\text{O}_2) (1.30 \times 10^{-2}) \text{NO}</td>
<td>(3.20 \times 10^{-3})</td>
</tr>
<tr>
<td>2</td>
<td>(2.20 \times 10^{-2}) (1.30 \times 10^{-2}) \text{NO}</td>
<td>(6.40 \times 10^{-3})</td>
</tr>
<tr>
<td>3</td>
<td>(1.10 \times 10^{-2}) (2.60 \times 10^{-2}) \text{NO}</td>
<td>(12.8 \times 10^{-3})</td>
</tr>
<tr>
<td>4</td>
<td>(3.30 \times 10^{-2}) (1.30 \times 10^{-2}) \text{NO}</td>
<td>(9.60 \times 10^{-3})</td>
</tr>
</tbody>
</table>

(a) Deduce the rate equation and find the value of the rate constant for this reaction.
(b) If the initial rate of consumption of oxygen was \(1 \times 10^{-3}\) mol L\(^{-1}\) s\(^{-1}\), what is the initial rate of formation of NO\(_2\)(g)?