Vorlesung "Modellierung von Zellprozessen"
Aufgabenblatt 2: Kinetik und Thermodynamik

WS 2009/2010, Dozent: Wolfram Liebermeister

1. **Normalised elasticities** (a) Compute and draw, for the following kinetic equation, the scaled elasticity with respect to the substrate concentration c.

$$v = \frac{V_{\max} c}{K_M + c}, \quad V_{\max} = 24\,\mathrm{mmol/min}, K_M = 0.6\,\mathrm{mM}$$

   (b) Compute and draw the scaled elasticity for the following kinetic equation v (uncompetitive inhibition) with respect to the substrate concentration c.

$$v = \frac{V_{\max} c}{K_M + c(1 + I/K_I)}, \quad V_{\max} = 24\,\mathrm{mmol/min}, K_M = 0.6\,\mathrm{mM}, I/K_I = 1.5$$

2. **Elasticities and response coefficients**. Consider the reaction system $X_1 \leftrightarrow Y \leftrightarrow X_2$ with external metabolites X_1 and X_2, an internal metabolite Y, and reversible mass-action kinetics

$$\begin{aligned} v_1 &= k_{+1}\, x_1 - k_{-1}\, y \\ v_2 &= k_{+2}\, y - k_{-2}\, x_2. \end{aligned}$$

   (a) Write down the stoichiometric matrix and compute the unscaled elasticities of v_1, $\bar{E}^{v_1}_{x_1} = \frac{\partial v_1}{\partial x_1}$ and $\bar{E}^{v_1}_{y} = \frac{\partial v_1}{\partial y}$ as well as the corresponding scaled elasticities $E^{v_1}_{x_1}$ and $E^{v_1}_{y}$.

   (b) Given values for the concentrations x_1 and x_2 and for the rate constants $k_{\pm 1}$ and $k_{\pm 2}$, compute the steady-state concentration $s(x_1, x_2)$ of Y and the corresponding steady-state flux values $J_1(x_1, x_2)$ and $J_2(x_1, x_2)$.

   (c) Compute the unscaled flux response coefficient $\bar{R}^{J_1}_{x_1} = \frac{\partial J_1}{\partial x_1}$. What does it tell you about the response coefficient for J_2? Try to explain the difference between the elasticity and the response coefficient in this example. Which of them is bigger? Why?

3. **Cycle of chemical reactions** Assume a cycle of chemical reactions $A \leftrightarrow B$, $B \leftrightarrow C$, $C \leftrightarrow A$ without cofactors. Show that there is no stationary, thermodynamically feasible flux distribution except for the (trivial) vanishing flux.

4. **ATP production in glycolysis.** Glycolysis from glucose to lactate effectively converts two ADP molecules into two ATP molecules. (a) Is this process thermodynamically feasible? Assume a decrease of Gibbs free energy by 205 kJ/mol for the conversion of Glucose into two Lactate molecules and increase of 49 kJ/mol for each ADP molecule converted to ATP. (b) Imagine alternative versions of glycolysis that convert glucose into lactate and produce other numbers of ATP molecules. What are the minimal and maximal numbers possible? (c) Assume, for simplicity, that the glycolytic flux is proportional to the total decrease of Gibbs free energy. Which number of ATP molecules produced would lead to (i) a maximal rate of ATP production and (ii) maximal efficiency, i.e. maximal ATP production per amount of glucose consumed?