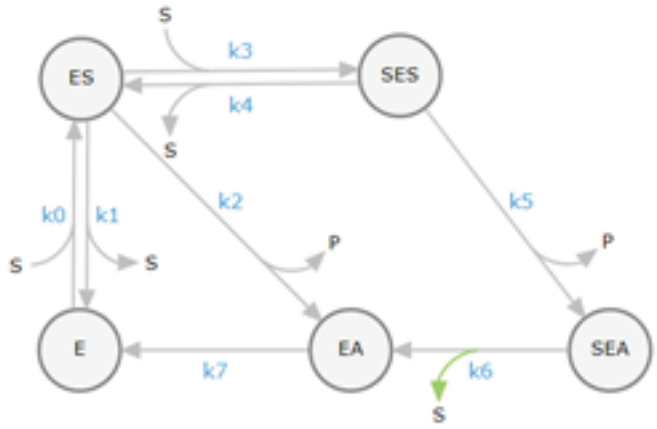
In many biological reactions, enzymes are used to facilitate the synthesis of a product. For the mechanism shown in Figure 1, an enzyme creates a product after binding with one or two substrate molecules.



$$E + S \rightleftharpoons ES \quad (1)$$

$$ES + S \rightleftharpoons SES \quad (2)$$

$$ES \rightarrow EA + P \quad (3)$$

$$SES \rightarrow SEA + P \quad (4)$$

$$SEA \rightarrow EA + S \quad (5)$$

$$EA \rightarrow E \quad (6)$$

In this reaction, *E* represents the enzyme, *S* is the substrate, *ES* and *SES* are enzyme complexes, *EA* and *SEA* are spent enzymes that need to be reduced to *E* to regain catalytic function, and *P* is the product.

Using this reaction scheme, develop the following deliverables:

Deliverable 1: Given that an enzyme's catalytic function is dependent on temperature, the relationship given in Equation 7 can be used to determine the rate constant for the reactions where a product is generated (Equations 3 and 4). Plot how the reaction rates for these two reactions, k_2 and k_5, changes with temperatures increasing from 4°C (refrigerated enzyme) to 65°C (above which proteins denature)

$$\ln k = \ln(T) + \frac{\Delta S}{T} + \frac{\Delta H}{T^2} \quad (7)$$

where *k* represents the specific reaction rate, *T* is the temperature in K of the reaction and values for ΔH and ΔS are given in Table 1.

Table 1. Values for reaction rate constant and activation energy calculations.

Reaction	ΔH [kJ/mol]	ΔS [kJ/mol K]
Reaction 3, for k_2	9.8×10^3	-52.6
Reaction 4, for k_5	47.4×10^3	-65.1

Deliverable 2: Based on general chemistry concepts, the change in concentration of a reactant or product can be calculated using the reaction rate, *k*, and the concentration of the reaction starting materials (i.e. reactants for a forward reaction, products for a reverse reaction). Set up the system of ordinary differential equations to determine the concentration of each component with time. Using Matlab and an established ode solver, solve your differential equations and plot the change in concentrations of the substrate, product, and enzyme for the reaction run at 37°C in a time

span of 0 to 0.5. The initial concentrations of substrate and enzyme are 0.1 and 2.6×10^{-3}, respectively.

Deliverable 3: Discuss the impact of changing the initial substrate concentration on the overall reaction. Support your discussion using calculations and graphs for concentrations ranging from 0.001 to 0.25.