CHEM 361A - Lecture 16 Activity

The Temperature Dependence of Rate Constants

In Class

1. The rate constant for the reaction of hydrogen with iodine is 2.45×10^{-4} M^{-1} s^{-1} at 302°C and 0.950 M^{-1} s^{-1} at 508°C.

   (a) Calculate the activation energy and Arrhenius exponential pre-factor for this reaction.

   (b) What is the value of the rate constant at 400°C

2. The growth of a bacterial colony can be modeled as a first-order process in which the rate of growth of the number of bacteria cells is proportional to the number of cells

$$\frac{dN}{dt} = kN$$

   (a) Use the first-order rate law expression above to show that the number of cells in the colony at any time is given by

$$N = N_0 e^{kt}$$

   where N_0 is the initial number of cells.

   (b) The generation time is the amount of time it takes for a given number of cells to double. Determine an expression for the generation time.

   (c) If the generation time for the bacteria is 75 minutes at 37°C, determine its rate constant.

   (d) The change in rate constants as a function of temperature is very important for the food industry as perishables need to be transported such that they have not spoiled by the time they reach consumers. Ratkowsky *et. al.* measured the rate constants of several bacteria strains. According to their data (shown in Figure 1), is it appropriate to apply an Arrhenius relationship to determine how the rate constant changes with temperature? Why?

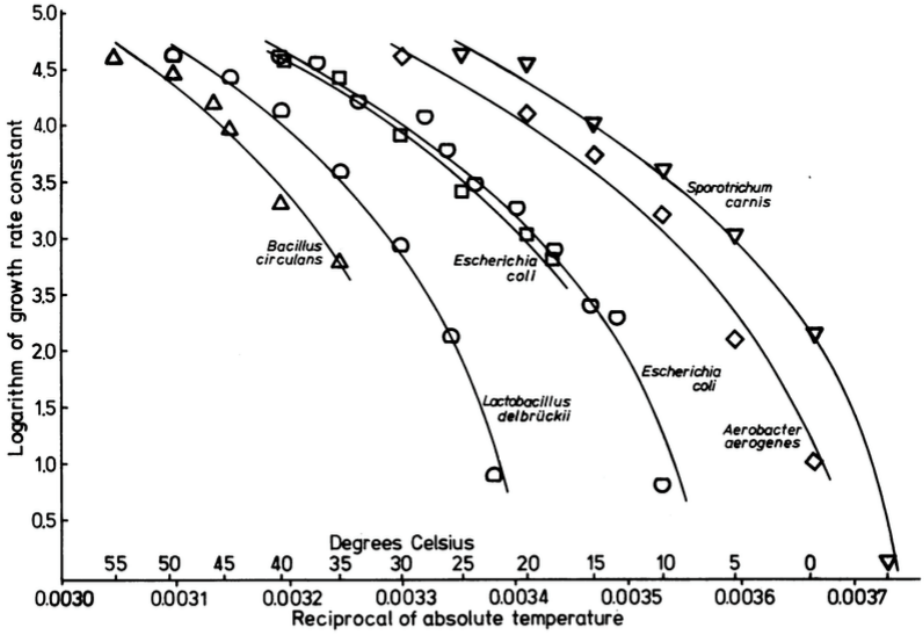

Figure 1: Arrhenius plot relating the natural logarithm of the rate constant with the inverse temperature for 6 bacteria strains. Image taken from Ratkowsky, D. A., et al. "Relationship between temperature and growth rate of bacterial cultures." Journal of Bacteriology 149.1 (1982): 1-5.

3. An experiment is performed on the parallel reaction found in Figure 2.

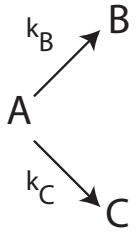

Figure 2: Schematic of a parallel reaction

(a) The following two statements were determined:

- The yield for B, Φ_B, at a given temperature is found to be 0.3
- The rate constants are described well by an Arrhenius expression with the activation energy of B and C formation being 27 and 34 kJ mol^{-1} respectively, with identical exponential pre-factors.

Demonstrate that these two statements cannot both be true at 298 K.

(b) At what temperature, if any, would these two statements be consistent? You may use WolframAlpha to help solve this.

Homework

4. The activation energy for the decomposition of benzene diazonium chloride is 99.1 kJ mol^{-1}. At what temperature will the rate be 25% greater than its rate at 25°C? (299.8 K)

5. A flask contains a mixture of compound A and compound B. Both compounds decompose by first-order processes. At 298 K, the half-life for A is 50 minutes and for B is 18 minutes.

   (a) If $[A]_0$=$[B]_0$, how long will it take for the concentration of A to be four times that of B? (3.37×10^3 s)

   (b) If $[A]_0$=$[B]_0$ and both processes have the same activation energy (E_a = 460 kJ mol^{-1}), how long will it take for the concentration of A to be four times that of B at 308 K? (8.13 s)