1. (10 points) The reaction \(2NO + O_2 \rightarrow 2NO_2\) is second order with a temperature-dependent rate constant, \(k\):

<table>
<thead>
<tr>
<th>(T) (K)</th>
<th>203.8</th>
<th>222.4</th>
<th>272.2</th>
<th>307.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>(k) (cm(^3)molec(^{-1}) s(^{-1})) / 10(^{-15})</td>
<td>2.67</td>
<td>4.17</td>
<td>11.5</td>
<td>20.9</td>
</tr>
</tbody>
</table>

Using these data only, determine \(\Delta H^\ne\) for this reaction over this range. [An appropriate plot makes the analysis easy.]

The appropriate equation to plot is the following:

\[
\ln \left( \frac{k}{T} \right) = \ln \left( \frac{k_b}{h \epsilon} \right) + \frac{\Delta S^\ne}{R} - \frac{\Delta H^\ne}{R} \frac{1}{T}
\]

The slope of this plot is related to the enthalpy of activation.

\[
\Delta H^\ne = 747.6 \text{ K} \left( \frac{8.3144349 \text{ J K}^{-1} \text{ mole}^{-1}}{8.3144349 \text{ J K}^{-1} \text{ mole}^{-1}} \right) = 6.216 \text{ kJ mole}^{-1}
\]

[Note that the question specifically asked for the enthalpy of activation. It did NOT ask for the activation energy. The two parameters are not the same.]

2. (4 points) The decay of \(^{60}\)Co to form \(^{60}\)Ni by gamma ray emission has been used by physical chemists, such as former Delaware professor Conrad Trumbore, as a gamma-ray source in the study of radiation damage in biological systems. The half-life for the first-order decay of \(^{60}\)Co is \(1.9 \times 10^3\) days. What is the first-order rate constant for this process?

By rearrangement, one finds the relation: \(k = \frac{\ln 2}{t_{1/2}} = \frac{\ln 2}{1.9 \times 10^3 \text{ day}^{-1}} = 3.6 \times 10^{-4} \text{ day}^{-1}\)

This can be expressed in other time units as \(1.5 \times 10^{-5} \text{ h}^{-1} = 2.5 \times 10^{-7} \text{ min}^{-1} = 4.2 \times 10^{-9} \text{ s}^{-1}\).

3. (6 points) Consider a bimolecular solution-phase reaction in water, for which the diffusion coefficient at 298.15 K is \(2.25 \times 10^{-9}\) m\(^2\) s\(^{-1}\). [You may assume that all the reactants diffuse similarly to the water.] Assuming the reacting molecules are roughly 1.0 Angström unit in diameter, estimate the maximum rate constant for the reaction under these conditions.

The question is answered by calculating the maximum rate constant for diffusion control:

\[
k_D = 4\pi N_0 (r_A + r_B) (D_A + D_B)
\]

\[
= 4\pi (6.02211415 \times 10^{23} \text{ mole}^{-1}) (1 \times 10^{-10} \text{ m}) (2 \times 2.25 \times 10^{-9} \text{ m}^2 \text{ s}^{-1})
\]

\[
= 3.41 \times 10^6 \frac{\text{m}^3}{\text{mole} \cdot \text{s}} = 3.41 \times 10^9 \frac{\text{dm}^3}{\text{mole} \cdot \text{s}}
\]