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Activation Energy of Corn syrup

Research Question:
What is the activation energy of Karo Brand Corn Syrup derived from using the Arrhenius Equation?

Context:
Machinery with moving parts and lubrication
Background

- Viscosity is a measurement of the frictional forces acting on a body in a liquid
- Dynamic viscosity: fluid resistance to flow when an external force is applied
- Kinematic viscosity: fluid resistance under the influence of gravity
- Measured through capillary viscometer
- Stokes Law: \( F_{\text{viscosity}} = 6\pi r \eta v \downarrow T \)

Weight = Friction + Bouyancy

\[
mg = 6\pi r \eta v \downarrow T + \frac{4}{3} \rho \downarrow l g \pi r \uparrow 3 \\
\eta = 2r \uparrow 2 \frac{g(\rho \downarrow b - \rho \downarrow l)}{9 v \downarrow T}
\]
Background

• Activation Energy of a viscous fluid is energy needed for a liquid to flow
• Viscosity is shown to decrease with temperature in liquids
• Modified to include viscosity instead of reaction rate

• $\eta$: Viscosity
• $A$: Entropic factor
• $E_a$: Activation energy
• $R$: Universal gas constant
• $T$: Absolute temperature

Normal Equation
$$k = Ae^{\frac{E_a}{RT}}$$

Modified Equation
$$\eta = Ae^{\frac{E_a}{RT}}$$
## Variables

<table>
<thead>
<tr>
<th>Variable Type</th>
<th>Variable</th>
<th>Effect on Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Independent</td>
<td>Temperature</td>
<td>Varied by heating corn syrup</td>
</tr>
<tr>
<td>Dependent</td>
<td>Terminal Velocity</td>
<td>Measured by Tracker</td>
</tr>
<tr>
<td>Controlled</td>
<td>Same metal sphere</td>
<td>By changing sphere, it could affect terminal velocity and viscosity</td>
</tr>
<tr>
<td>Controlled</td>
<td>Type of fluid</td>
<td>Differing fluids have different densities and thus different viscosities</td>
</tr>
</tbody>
</table>
Methodology

Equipment:
• Glucose Syrup
• Measuring Cylinder
• Balancing Scale
• Vernier Calliper
• Metal Ball
• Rare Earth magnet
• Camera
• Thermometer

Methodology:
1. Measure mass of corn syrup and divide by volume to find density.
2. Measure radius of ball and divide this value by its mass to find density.
Methodology

3. Pour 800 mL syrup into beaker and microwave to approximately 50°C

4. Drop ball into syrup 3 times and record temperature of syrup each time the temperature falls by 3 degrees celsius.

5. Using Tracker, calculate terminal velocity by graphing displacement and time and finding its slope.
   - There are approximately 2800 data points, so any outliers were removed.
Raw Data

Terminal Velocity Vs Temperature

- Temperature (K) range from 295 to 325
- Terminal Velocity (m/s) range from 0 to 8000

Graph shows a positive correlation between temperature and terminal velocity.
Original Equation

\[ \eta = 2r^2 g(\rho_{b} - \rho_{l})/9v_{T} \]

Where:
- \( \eta \) - Kinematic viscosity
- \( r \) - Radius of sphere
- \( \rho_{b} \) - Density of ball
- \( \rho_{l} \) - Density of liquid
- \( v_{T} \) - Terminal velocity
- \( g \) - Gravitational value on Earth
Raw Data

Viscosity vs Temperature

- Viscosity (Pa-s) vs Temperature (K)
- Graph showing a decrease in viscosity with increasing temperature.
Linearization of Equation

\[ \eta = Ae^{E/a} / RT \]

\[ \ln \eta = \ln(Ae^{E/a} / RT) \]

\[ \ln \eta = \ln A + \ln e^{E/a} / RT \]

\[ \ln \eta = \ln A + E/a / R \cdot 1/T \]
Results

\[ \ln(\eta) = \ln(A) + \frac{Ea}{R \cdot 1/T} \]

TREND \quad y = 11076x - 35.885
MAX \quad y = 12201x - 39.450
MIN \quad y = 10014x - 32.372

\textbf{Ln(\eta) vs inverse temperature for corn syrup}
Final Values

\[ E\downarrow a / R = \text{slope} \]

\[ E\downarrow a \approx 92.1 \, \text{kJ/mol} \]

\[ \text{Error in value} = \frac{\text{max slope} - \text{min slope}}{2} \]
\[ \text{Error in value} = \frac{(12201 - 10014)}{2} \]
\[ \text{Error in value} \approx 1.1 \, \text{kJ/mol} \]

- The measured activation energy for activation energy of corn syrup 92.1 ± 1.1 kJ/mol.
- This corresponds well with the theoretical value for quoted literature values for fructose solution activation energy range from 20-100 kJ/mol depending on the syrup concentration. The Karo brand corn syrup used is a concentrated solution of fructose and glucose sugars.
Sources of Error

Random errors:
• variations in temperatures in the liquid due to its high density

Systematic Error:
• evaporation of the water from the corn syrup during heating changes the concentration and therefore viscosity

Improvements

More accurate ways to measure temperature
Conclusion

• Overall, the use of the modified Arrhenius equation to measure the activation energy of a fluid turned out to be an accurate method. The value of activation energy was calculated to be $92.1 \pm 1.1 \text{ kJ/mol}$

Further Research

• Vary the concentration of the substance and see how that affects viscosity and activation energy of a fluid such as glycerol
• See if this equation holds true for temperatures above 50 degrees Celsius and below room temperature
Bibliography


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