Section 15.5
Activation Energy and Temperature

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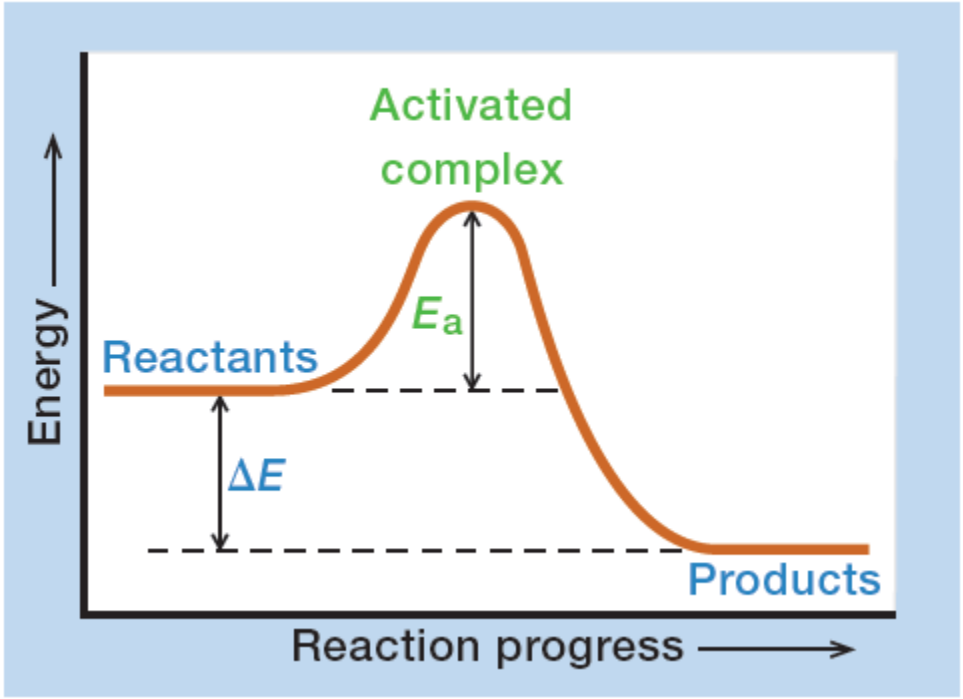
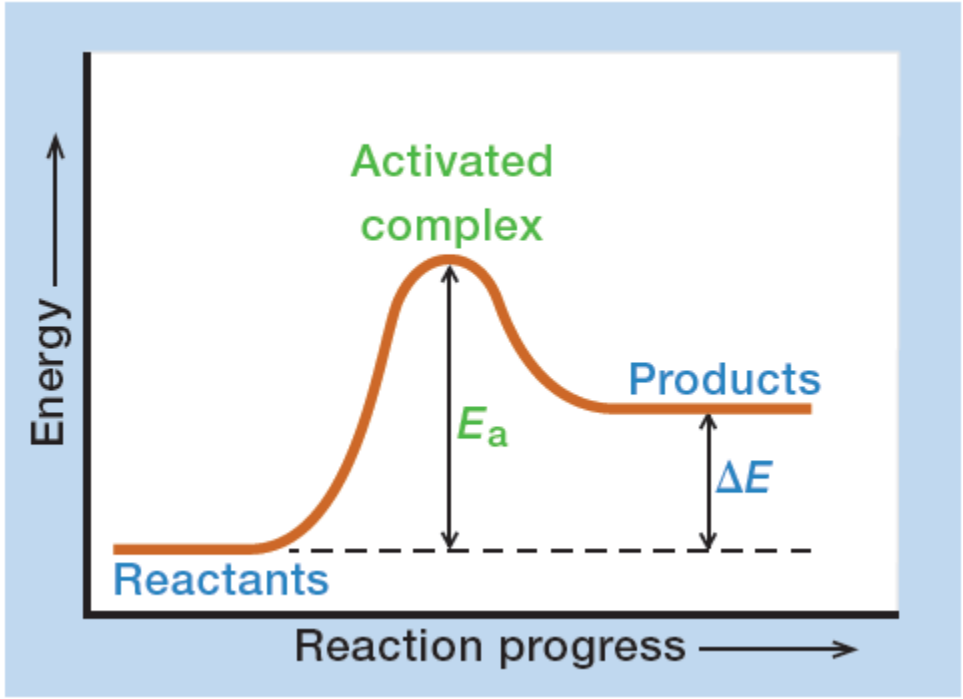
Activation Energy and Temperature

In this section…

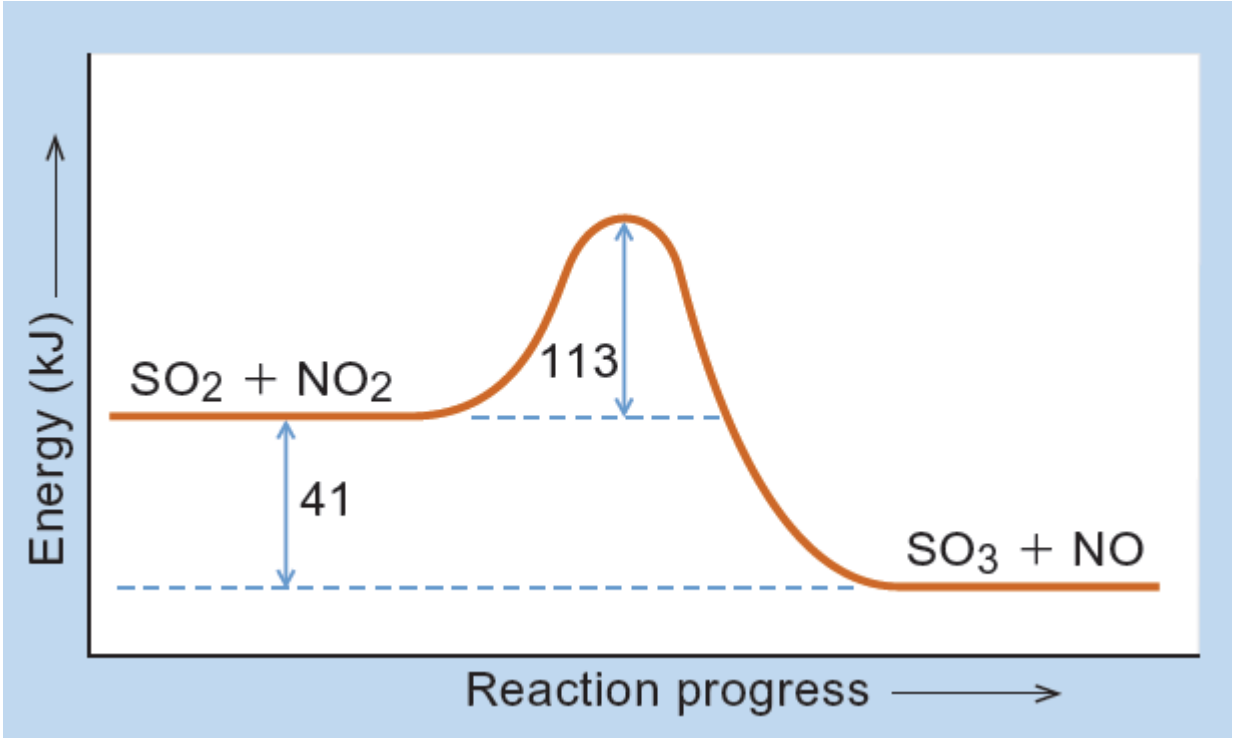
a. Reaction coordinate diagrams
b. The Arrhenius equation
c. Temperature, E_a and k
d. Graphical determination of $_{Ea}$

Reaction Coordinate Diagrams

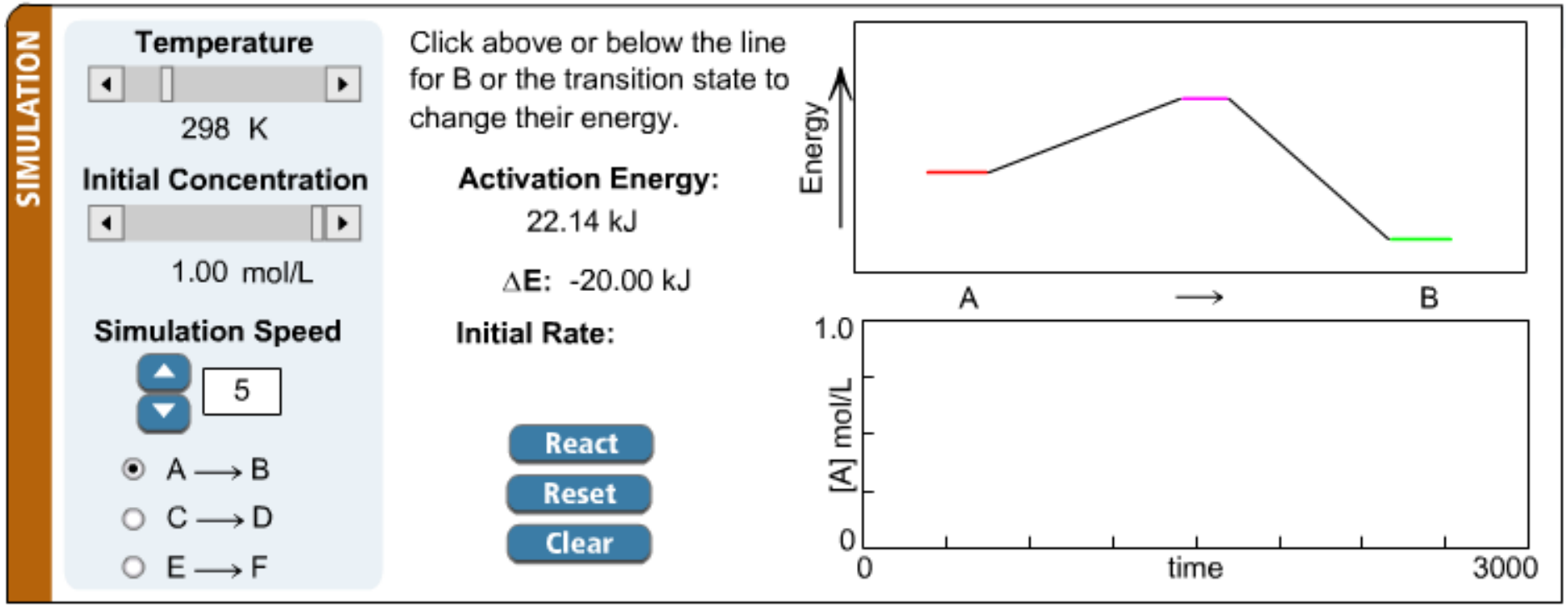




Numerical connection between E_a and ΔE



Activation Energy, Temperature and Rate

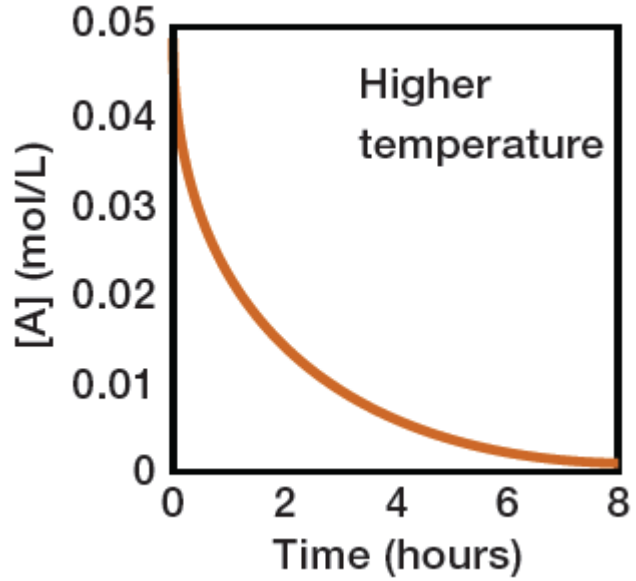


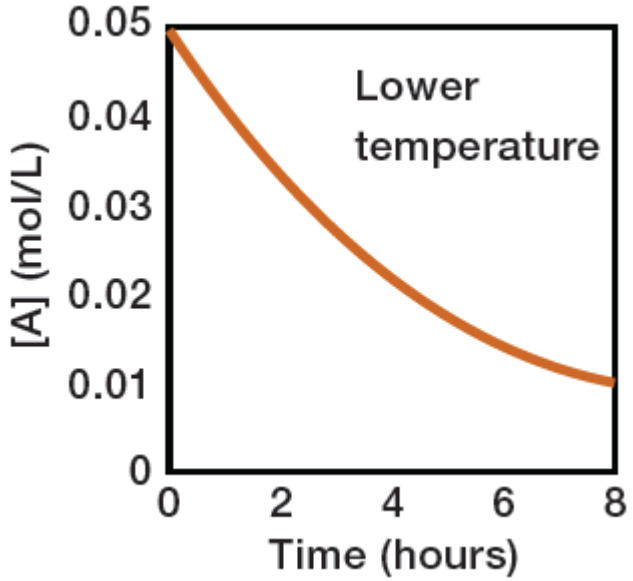
Activation Energy, Temperature and Rate

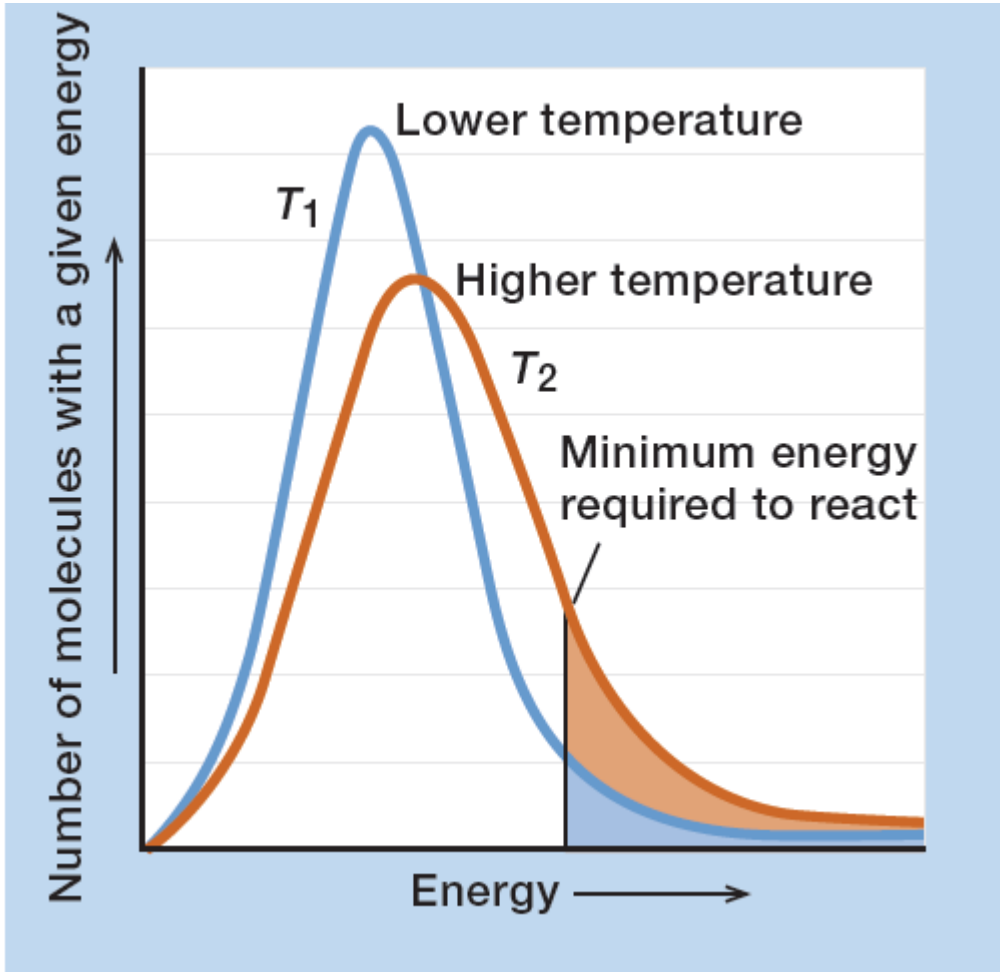
Trends:

- As E_a decreases, rate increases
- As T increases, rate increases

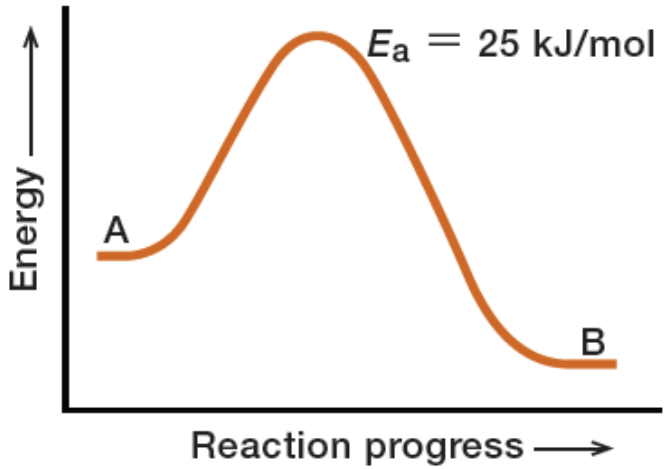
Why do reactions go faster at higher temperature?

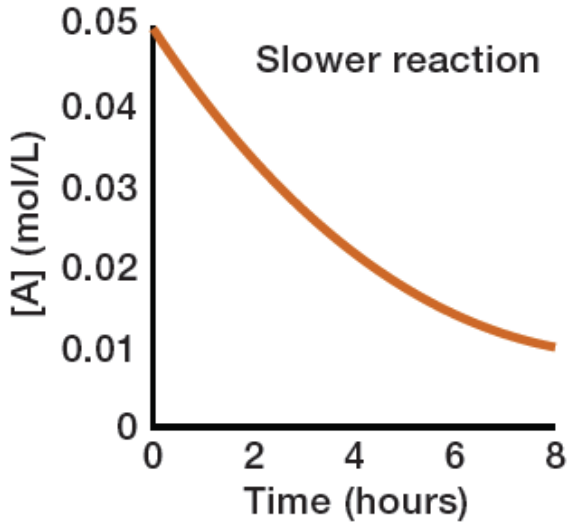


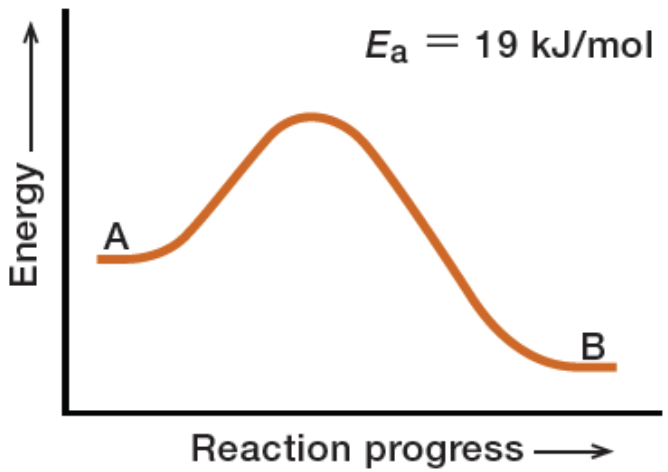


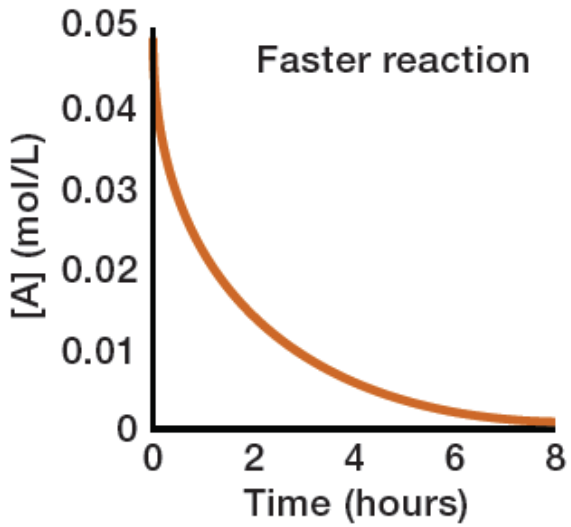


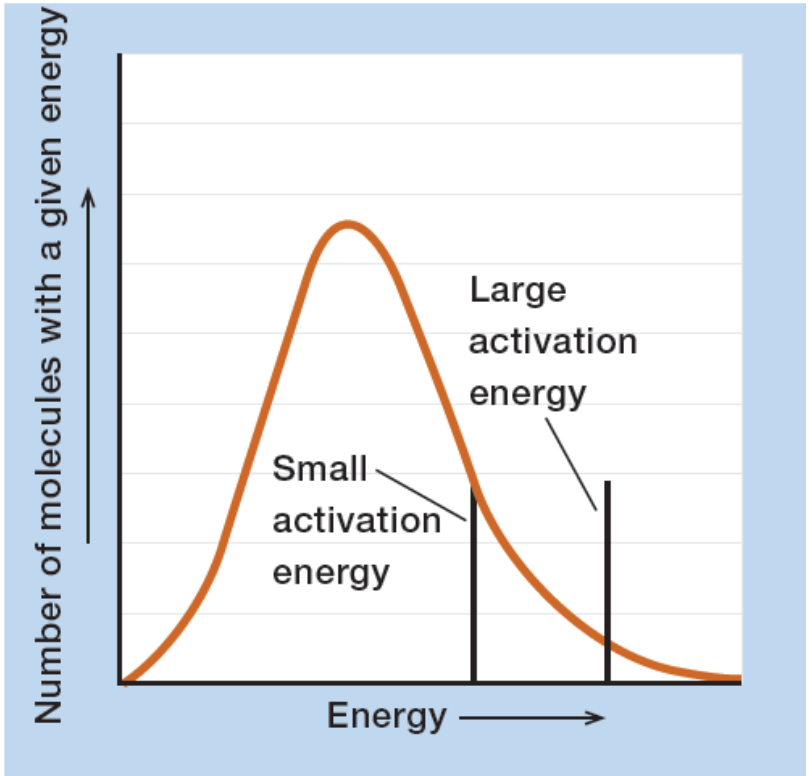
Why do reactions go faster with lower activation energy?











The Arrhenius Equation

$$k = Ae^{-E_a/RT}$$

k = rate constant
A = frequency factor
E_a = activation energy
R = gas constant (8.3145 J/K ·mol)
T = temperature (K)

Trends:

As T↑:

As E_a↑:

The Arrhenius Equation: Two Point Version

$$\ln \frac{k_2}{k_1} = \frac{-E_a}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

k_1 = rate constant at temperature 1
k_2 = rate constant at temperature 2
T_1 = temperature 1 (K)
T_2 = temperature 2 (K)
E_a = activation energy
R = gas constant (8.3145 J/K ·mol)

General Use:

There are five variables. If you know 4 of Them you can solve for the 5th.

The Arrhenius Equation: Two Point Version

The activation energy for the gas phase decomposition of *t*-butyl propionate is 164 kJ.

$$\ln \frac{k_2}{k_1} = \frac{-E_a}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

$C_2H_5COOC(CH_3)_3(g) \rightarrow (CH_3)_2C{=}CH_2(g) + C_2H_5COOH(g)$

The rate constant for this reaction is 3.80×10^{-4} s^{-1} at 528 K. What is the rate constant at 569 K?

The Arrhenius Equation: Two Point Version

The rate of a reaction triples when the temperature is increased from 280 °C to 300 °C. What is the activation energy?

$$\ln \frac{k_2}{k_1} = \frac{-E_a}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

The Arrhenius Equation: Graphical Determination of E_a

$$k = Ae^{-E_a/RT}$$

k = rate constant
A = frequency factor
E_a = activation energy
R = gas constant (8.3145 J/K ·mol)
T = temperature (K)

$$\ln(k) = \ln(A) - \frac{E_a}{R}\frac{1}{T}$$

y = b + m x

Collect k vs. temperature data

Plot ln(k) vs. 1/T
E_a = - slope x R

Graphical Determination of E_a

$$\ln(k) = \ln(A) - \frac{E_a}{R}\frac{1}{T}$$

$$N_2O_5(g) \rightarrow 2\ NO_2(g) + \tfrac{1}{2}\ O_2(g)$$

Temperature (K)	k (s^{-1})
298	3.46×10^{-5}
328	1.50×10^{-3}
358	3.34×10^{-2}
378	0.210