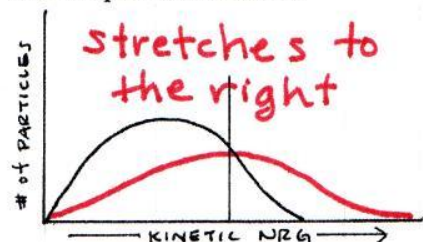


15 • Chemical Kinetics

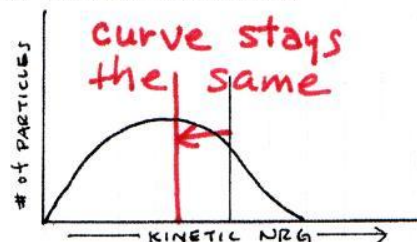
Station 1 – KINETIC ENERGY DIAGRAMS

Draw how the KE diagram would change if:

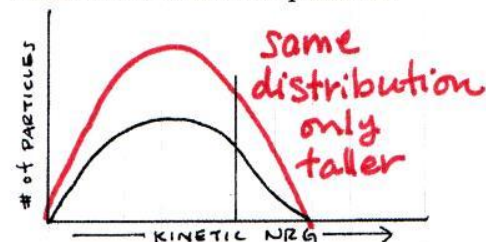
the temperature of the sample is increased.



a catalyst is added to the reaction mixture.



more chemical is added at the same temperature.



What is the name of the vertical line intersecting the graph? threshold energy

Why do particles need kinetic energy to react?

The particles need to collide hard enough to form the higher potential energy activated complex.

15 • Chemical Kinetics

Station 2 – POTENTIAL ENERGY DIAGRAMS

The energy of the **reactants** is 30 kJ/mol.

$\Delta H = -20 \text{ kJ/mol}$ exothermic; downhill

$E_a = +40 \text{ kJ/mol}$

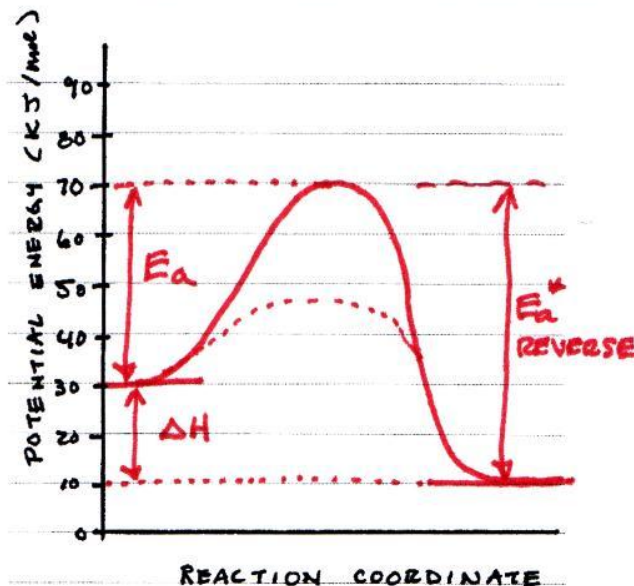
Draw the PE curve.

The energy of the **products** is 10 kJ/mol

The **activation energy** for the **reverse** reaction is 60 kJ/mole

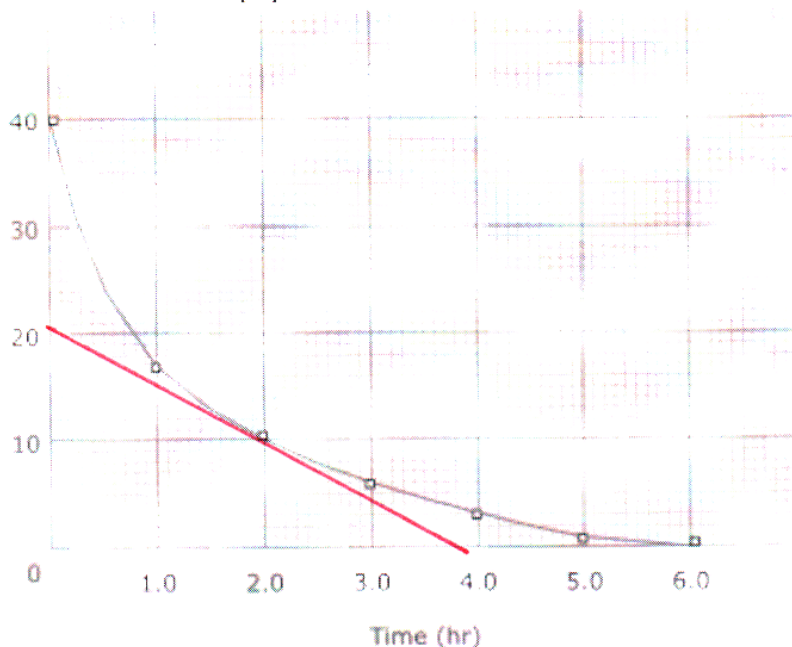
Draw the same curve with a catalyst included. (-----)

Any lower energy line is OK.



15 • Chemical Kinetics

The vertical axis is [R] in mol·L⁻¹



Station 3 – RATE FROM GRAPHS

Show your work for these two problems.

The **average** rate of the reaction for the first 2.0 hours is _____.

$$\frac{\Delta \text{Reactant}}{\Delta \text{time}} = \frac{40 - 10}{2.0 \text{ hr}} = \frac{30}{2.0} = \boxed{15 \text{ mol} \cdot \text{L}^{-1} \cdot \text{hr}^{-1}}$$

The **instantaneous** rate of the reaction at 2.0 hours is _____.

SLOPE OF A TANGENT LINE
at 2.0.

$$\frac{\text{RISE}}{\text{RUN}} = \frac{20 \text{ mol} \cdot \text{L}^{-1}}{3.8 \text{ hr}} = \boxed{5.26 \text{ mol} \cdot \text{L}^{-1} \cdot \text{hr}^{-1}}$$

15 • Chemical Kinetics

Station 4 – CALCULATING RATES OF REACTION

Consider the combustion of propane, $\text{C}_3\text{H}_8(\text{g}) + 5 \text{O}_2(\text{g}) \rightarrow 3 \text{CO}_2(\text{g}) + 4 \text{H}_2\text{O}(\text{g})$

The rate of disappearance of $\text{O}_2(\text{g})$ is $6.4 \text{ mol} \cdot \text{L}^{-1} \cdot \text{s}^{-1}$

What is the rate of disappearance of $\text{C}_3\text{H}_8(\text{g})$? $\text{Rate}_{\text{C}_3\text{H}_8} = \frac{1}{5} 6.4 \text{ mol} \cdot \text{L}^{-1} \cdot \text{s}^{-1} = \boxed{1.28 \text{ mol} \cdot \text{L}^{-1} \cdot \text{s}^{-1}}$

What is the rate of appearance of $\text{CO}_2(\text{g})$? $\frac{1}{5}(6.4) = \frac{1}{3} \text{Rate}_{\text{CO}_2} = \boxed{3.84 \text{ mol} \cdot \text{L}^{-1} \cdot \text{s}^{-1}}$

What is the rate of appearance of $\text{H}_2\text{O}(\text{g})$? $\frac{1}{5}(6.4) = \frac{1}{4} \text{Rate}_{\text{H}_2\text{O}} = \boxed{5.12 \text{ mol} \cdot \text{L}^{-1} \cdot \text{s}^{-1}}$

NOTE: Signs are not necessary because the words "disappearance" and "appearance" are used.

15 • Chemical Kinetics

Station 5 – RATE LAWS – THE METHOD OF INITIAL RATES

Here is some initial rate data for the reaction, $A + B \rightarrow 2C$.

[A]	[B]	Rate ($\text{mol} \cdot \text{L}^{-1} \cdot \text{s}^{-1}$)
0.40	0.10	3.5×10^3
0.20	0.10	1.8×10^3
0.20	0.50	4.5×10^4

Handwritten notes: $\times 2$ (next to first two rows), $\times 5$ [(next to last two rows), ~ 2 (next to first two rows), $] 2.5$ (next to last two rows)

- a) Determine the **orders** of reactants A 1 and B 2
- b) Write the **rate law** for this reaction: $\text{Rate} = k [A] [B]^2$
- c) Calculate the value of the **rate constant, k**, with **units**. _____

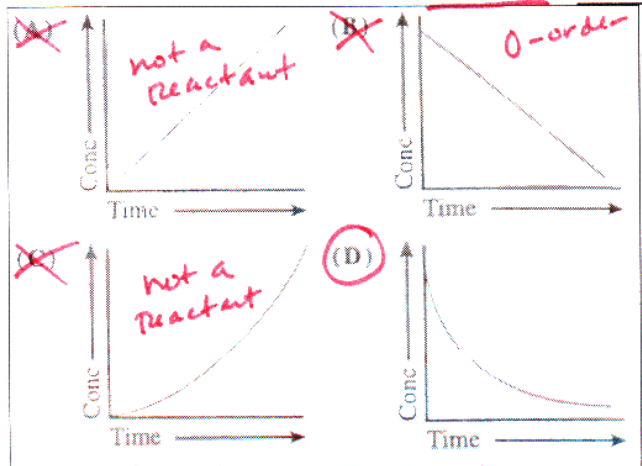
$$k = \frac{\text{Rate}}{[A][B]^2} = \boxed{8.75 \times 10^5 \text{ L}^2 \cdot \text{mol}^{-2} \cdot \text{s}^{-1}}$$

$$\frac{\text{mol} \cdot \text{L}^{-1} \cdot \text{s}^{-1}}{\text{mol}^3 \cdot \text{L}^{-3}} = \text{mol}^{-2} \cdot \text{L}^2 \cdot \text{s}^{-1}$$

15 • Chemical Kinetics

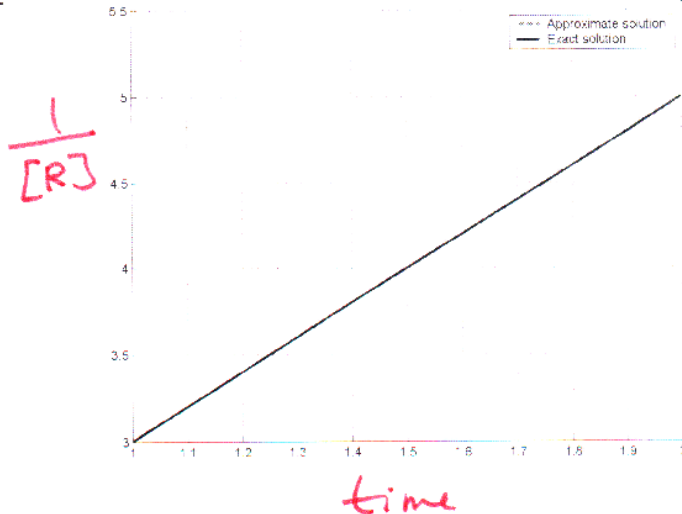
Station 6 – ORDERS OF REACTIONS – GRAPHICAL METHODS

Which graph corresponds to the change in concentration of a reactant that is first order?



Process of elimination. you can't really tell if this is 1st or 2nd order.

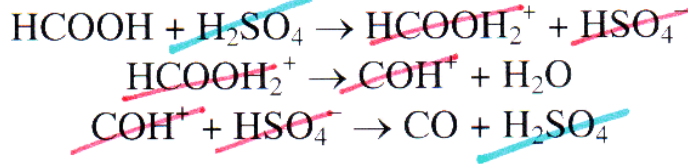
This graph is a chemical that is second order. The horizontal axis is time. What is the vertical axis? $\frac{1}{[R]}$



15 • Chemical Kinetics

Station 7 - REACTION MECHANISMS

Consider this reaction mechanism:



From THE FILM

- a) What is the overall reaction? $\text{HCOOH} \rightarrow \text{CO} + \text{H}_2\text{O}$
- b) List any "intermediates." $\text{HCOOH}_2^+, \text{HSO}_4^-, \text{COH}^+$
- c) List any catalysts. H_2SO_4
- d) If the first step is the slow step, what is the rate law? $\text{Rate} = k [\text{HCOOH}]$

NOTE: H_2SO_4 is not a reactant.

15 • Chemical Kinetics

Station 8 - HALF LIFE PROBLEMS

- a) A first-order chemical has a half-life of 8.00 minutes. How long will it take for 93.75% of this chemical to decay?

100 50 25 12.5 6.25

$100 - 93.75\% = 6.25\% \text{ LEFT!}$

$4 \times 8 \text{ min} = \boxed{32.0 \text{ min}}$

- b) The reaction $\text{X} \rightarrow \text{Y}$ follows first-order kinetics with a half-life of 4.00 minutes. What is the value of k ? If the initial concentration of X is 3.6 M, what is the concentration after 15.0 minutes?

$$\begin{aligned}
 \ln 2 &= k t_{1/2} \\
 k &= \frac{.693}{4.00 \text{ min}} = \\
 &= 0.17325 \text{ min}^{-1} \\
 k &= \boxed{0.173 \text{ min}^{-1}}
 \end{aligned}$$

$$\begin{aligned}
 \ln(x) - \ln(3.6) &= -(0.173 \text{ min}^{-1})(15.0 \text{ min}) \\
 \ln x - 1.28 &= -2.595 \\
 \ln x &= \frac{-2.595 + 1.28}{1} \\
 \ln x &= -1.315 \\
 x &= e^{-1.315} = \boxed{0.268 \text{ M}}
 \end{aligned}$$

Formula:

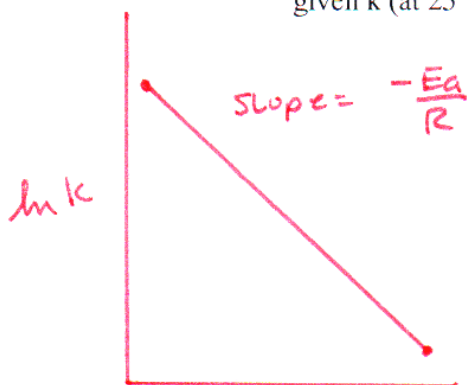
$$\ln[A]_t - \ln[A]_0 = -kt$$

15 • Chemical Kinetics

Station 9 – THE ARRHENIUS EQUATION

Calculate the activation energy, E_a , for $\text{N}_2\text{O}_5(\text{g}) \rightarrow 2 \text{NO}_2(\text{g}) + \frac{1}{2} \text{O}_2(\text{g})$

given k (at 25°C) = $3.46 \times 10^{-5} \text{ s}^{-1}$ and k (at 50°C) = $1.10 \times 10^{-3} \text{ s}^{-1}$.



slope = $-\frac{E_a}{R}$

$$25^\circ\text{C} \quad \frac{1}{298\text{K}} = .0033557 \quad \ln(3.46 \times 10^{-5}) = -10.27$$

$$50^\circ\text{C} \quad \frac{1}{323\text{K}} = .00309597 \quad \ln(1.10 \times 10^{-3}) = -6.812$$

$$\frac{\text{RISE}}{\text{RUN}} = \frac{(-6.812) - (-10.27)}{.0033557 - .00309597} = \frac{-3.458}{.00025973}$$

$$= 13,313.8 = -\frac{E_a}{R}$$

$$E_a = + (13,313.8) \cdot 8.31 \frac{\text{J}}{\text{mol}\cdot\text{K}}$$

$$= +110,637 \text{ J/mol}$$

$$= \boxed{+111 \text{ kJ/mol}}$$

Formula:

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

$$R = 8.31 \text{ J mol}^{-1} \text{ K}^{-1}$$

* I HAVE THIS REVERSED

$$(-10.27) - (-6.812)$$