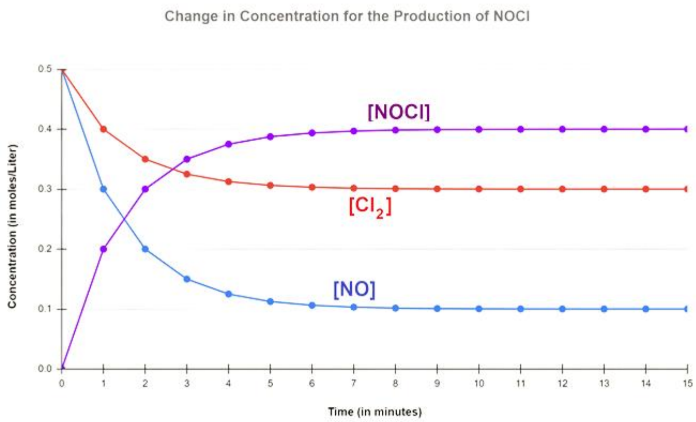
UNIT 5 KEY CONCEPTS

Kinetics

Use this *Key Concepts* Worksheet to follow along with the Unit 5 Summary Video.

Topic 1 – Reaction Rates

$$2\ NO(g) + Cl_2(g) \rightarrow 2\ NOCl(g)$$



What do you notice about the rates of NO and NOCl?

What do you notice about the coefficients of NO and NOCl?

How does the rate of Cl_2 compare to the rate of NO?

Determine the rate of change of [NOCl] in the time interval from 0 to 1 minute.

If the rate of change of [NOCl] in the time interval from 0 to 1 minute is $0.20\ \frac{M}{min}$, then estimate the rate of change of [Cl_2] over the same time interval.

Factors Affecting the Rate of a Reaction

1. Temperature
2. Concentration
3. Particle Size / Surface Area
4. Presence of a Catalyst
5. Chemical Nature of the Reactants

Topic 2 – Introduction to Rate Law

$$2\ NO(g) + H_2(g) \rightarrow N_2O(g) + H_2O(g)$$

Exp.	[NO]	[H_2]	Initial Rate (M/s)
1	0.30 M	0.35 M	0.00284
2	0.60 M	0.35 M	0.0113
3	0.60 M	0.70 M	0.0227

What is the order of the reaction with respect to NO?

What is the order of the reaction with respect to H_2?

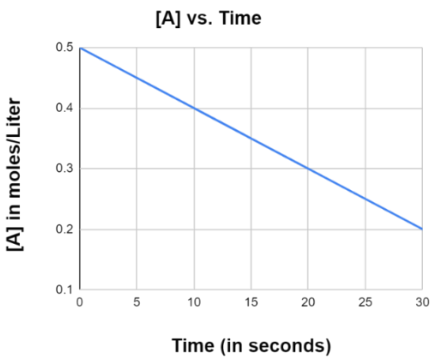
Write the rate law for this reaction.

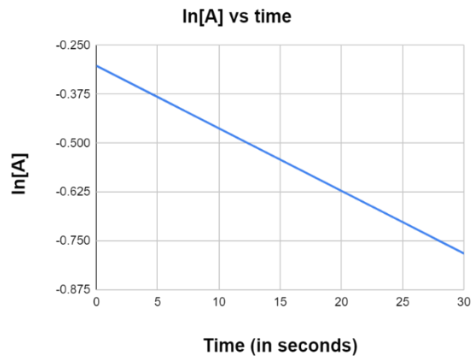
What is the overall order of this reaction?

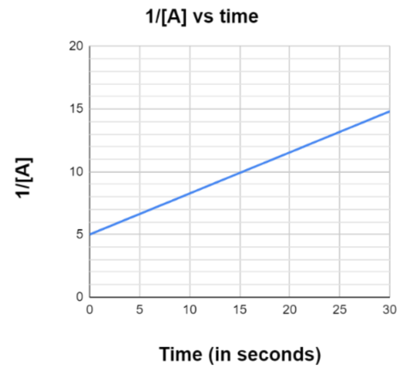
Calculate the rate constant k for the reaction at this temperature, with correct units.

Copyright ©2024 Jeremy Krug & Ultimate Review Packet

Annual license required. Do not share or post online.







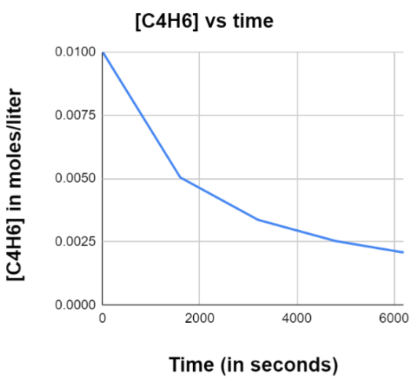
If this plot is a straight line, the reaction is **<u>0th order</u>**.

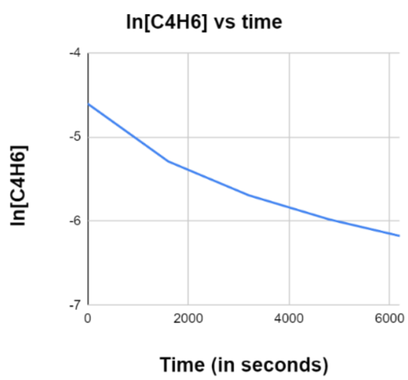
If this plot is a straight line, the reaction is **<u>1st order</u>**.

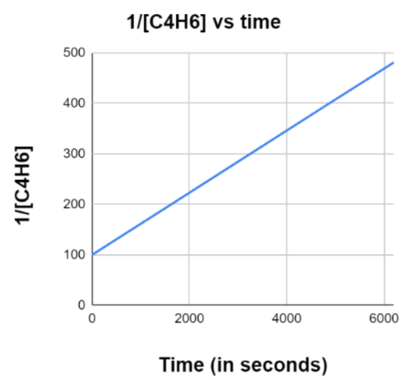
If this plot is a straight line, the reaction is **<u>2nd order.</u>**

The rate constant k is equal to the absolute value of the slope of the line.

The reaction **2 C_4H_6 → C_8H_{12}** is studied. The following graphs are produced and used to analyze the reaction.







(a) What is the order of this reaction with respect to C_4H_6?

(b) Write the rate law for this reaction.

Topic 3 – Concentration Changes Over Time

Integrated Rate Laws

For a 1st order process: $$\ln[A]_t - \ln[A]_0 = -k\,t$$

A first order reaction has a rate constant of 4.00×10^{-3} s^{-1} at 350 K. If the reactant begins with a concentration of 0.25 M, what will be the concentration after 95 s?

We are sometimes asked to calculate the ***half-life*** of a first-order process. $$t_{1/2} = \frac{0.693}{k}$$

Copyright ©2024 Jeremy Krug & Ultimate Review Packet Annual license required. Do not share or post online.

In the previous problem, the first-order reaction had a rate constant of 4.00×10^{-3} s^{-1}. What is the half-life of this process, in seconds?

	Rate Law	Units for *k*	Integrated Rate Law
0th order	Rate = k	M s^{-1}	$[A]_t - [A]_0 = -kt$
1st order	Rate = $k[A]$	s^{-1}	$\ln[A]_t - \ln[A]_0 = -kt$
2nd order	Rate = $k[A]^2$	M^{-1} s^{-1}	$\frac{1}{[A]_t} - \frac{1}{[A]_0} = kt$

Topic 4 – Elementary Reactions

This reaction has two elementary steps.

Each step can be described with its own rate law.

$$O_3(g) \leftrightharpoons O_2(g) + O(g)$$
$$O_3(g) + O(g) \rightarrow 2\,O_2(g)$$

Bimolecular step – a step in which two molecules react

Unimolecular step – a step in which one molecule decays on its own

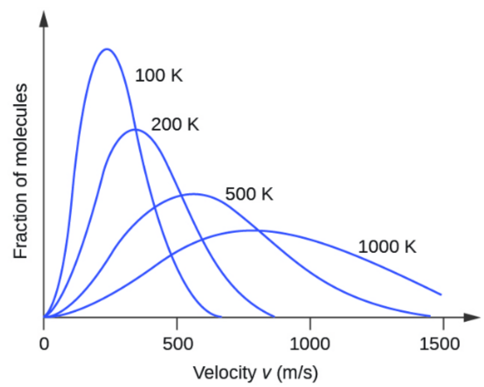
Termolecular steps (3 molecules) are quite rare (and usually very slow!)

Topic 5 – Collision Model

$$H_2 + Cl_2 \rightarrow 2\,HCl$$

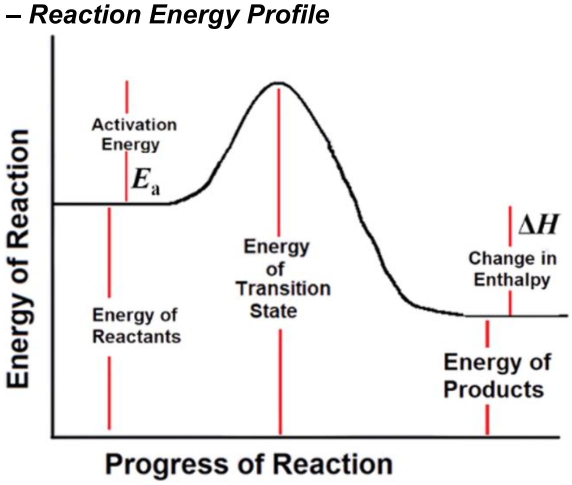
When the two molecules collide, they have to collide with

1. Sufficient Energy
2. Correct Orientation



Maxwell-Boltzmann Distribution Curve

Topic 6 – Reaction Energy Profile



Lowering the activation energy speeds up the reaction

Two 'humps' imply the reaction has two steps.

Copyright ©2024 Jeremy Krug & Ultimate Review Packet

Annual license required. Do not share or post online.

Kinetics

Topic 7 – Introduction to Reaction Mechanisms

Many reactions take place in two or more steps.

$$NO_2(g) + F_2(g) \rightarrow NO_2F(g) + F(g)$$
$$NO_2(g) + F(g) \rightarrow NO_2F(g)$$

F is the *reaction intermediate*

If we know which of these two steps is the *slow step*, we can also determine the rate law!

Topic 8 – Reaction Mechanism and Rate Law

Determine the rate law of this two-step reaction.

$$NO_2(g) + F_2(g) \rightarrow NO_2F(g) + F(g) \quad \text{(slow)}$$
$$NO_2(g) + F(g) \rightarrow NO_2F(g) \quad \text{(fast)}$$

The slow step determines the rate of the overall reaction.

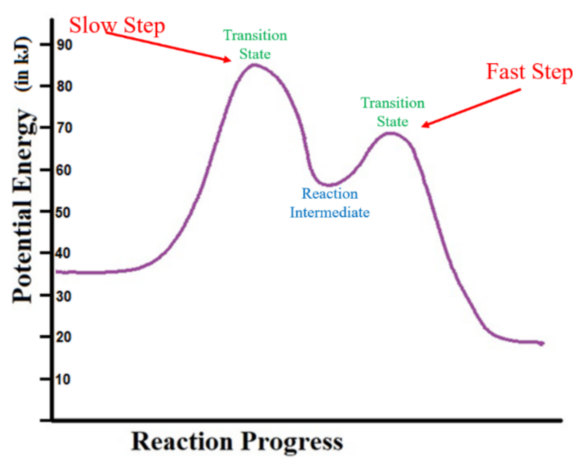
Topic 9 – Pre-Equilibrium Approximation

Using the mechanism below, (a) Write the overall equation for the reaction, and (b) determine the rate law of this reaction.

$$2\,NO(g) \leftrightharpoons N_2O_2(g) \quad \text{(fast, equilibrium)}$$
$$N_2O_2(g) + H_2(g) \rightarrow N_2O(g) + H_2O(g) \quad \text{(slow)}$$
$$N_2O(g) + H_2(g) \rightarrow N_2(g) + H_2O(g) \quad \text{(fast)}$$

A reaction intermediate cannot appear in the rate law!

Topic 10 – Multistep Reaction Energy Profile



Topic 11 – Catalysis

Using the mechanism below, (a) Write the overall equation for the reaction, (b) identify the reaction intermediate, and (c) identify the catalyst.

$$NH_2NO_2(aq) + OH^-(aq) \leftrightharpoons H_2O(l) + NHNO_2^-(aq)$$
$$NHNO_2^-(aq) \rightarrow N_2O(g) + OH^-(aq)$$

The reaction *intermediate* is produced in an early step, used up in a later step =

The *catalyst* is present at both the beginning and end, but never consumed =

Copyright ©2024 Jeremy Krug & Ultimate Review Packet Annual license required. Do not share or post online.