Kinetics
Rates of Chemical Reactions

Chemical Equilibrium

A ⇌ B

Reversible Reactions
(Dynamic Chemical Systems)

Dr. Ron Rusay

https://www.youtube.com/watch?v=dUMmoPdwBy4
https://www.youtube.com/watch?v=o1_D4FscMnU
Crash Course: https://www.youtube.com/watch?v=g5wNg_dKsYY

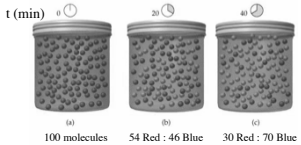
Kinetics
Rates of Chemical Reactions

Dr. Ron Rusay

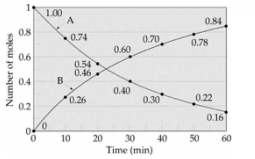
Chemical Reactions: Time & Progress

A ⇒ B

Red ⇒ Blue



100 molecules 54 Red : 46 Blue 30 Red : 70 Blue



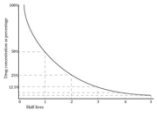
QUESTION

If we have the reaction A(*g*) → 2B(*g*) and the number of moles of A follows:

time	0	5 min	10 min
moles A	0.100	0.085	0.070

What is the number of moles of B at 10 min?

A. 0.060 mol
B. 0.200 mol
C. 0.140 mol
D. 0.100 mol
E. 0.030 mol

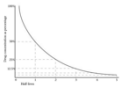


ANSWER

If we have the reaction A(*g*) → **2**B(*g*) and the number of moles of A is as follows,

time	0	5 min	10 min
moles A	0.100	0.085	0.070

What is the number of moles of B at 10 min?



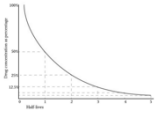
A. 0.060 mol
B. 0.200 mol
C. 0.140 mol
D. 0.100 mol
E. 0.030 mol

0.100 molA
-0.070 molA
0.030 molA x **2 molB/1molA**

Expressions of a Rate of Reaction

For any Chemical Reaction: a**A** + b**B** → c**C** + d**D**

$$\text{Rate} = -\frac{1}{a}\frac{\Delta[A]}{\Delta t} = -\frac{1}{b}\frac{\Delta[B]}{\Delta t} = \frac{1}{c}\frac{\Delta[C]}{\Delta t} = \frac{1}{d}\frac{\Delta[D]}{\Delta t}$$



Expressions of a Rate of Reaction

For the Chemical Reaction: a**A** + b**B** → c**C** + d**D**

$C_6H_{12}O_{6\,(aq)} + 6\,O_{2(g)} \rightarrow 6\,CO_{2\,(g)} + 6\,H_2O_{(g)} + energy$

$$\text{Rate} = -\frac{1}{a=1}\frac{\Delta[A]}{\Delta t} = -\frac{1}{b=6}\frac{\Delta[B]}{\Delta t} = \frac{1}{c=6}\frac{\Delta[C]}{\Delta t} = \frac{1}{d=6}\frac{\Delta[D]}{\Delta t}$$

$-1\Delta C_6H_{12}O_6/\Delta t = -1/6\Delta O_2/\Delta t = 1/6\Delta CO_2/\Delta t = 1/6\Delta H_2O/\Delta t$

$-6\Delta C_6H_{12}O_6/\Delta t = -1\Delta O_2/\Delta t = 1\Delta CO_2/\Delta t = 1\Delta H_2O/\Delta t$

$C_6H_{12}O_{6\,(aq)}$ disappears 6x faster than $O_{2(g)}$; *and*
$C_6H_{12}O_{6\,(aq)}$ disappears 6x faster than $CO_{2\,(g)}$ or $H_2O_{(g)}$

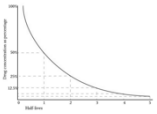
QUESTION

Chlorine dioxide (ClO_2), a yellow-green gas, which dissolves in water, is used as a disinfectant in some municipal water-treatment plants. It destroys the covid-19 virus. In a basic aqueous solution, it produces chlorate ion, ClO_3^-, and chlorite ion, ClO_2^-:

$2\,ClO_2(aq) + 2\,OH^-(aq) \rightarrow ClO_3^-(aq) + ClO_2^-(aq) + H_2O(l)$

Of the following choices, which would **not** be a correct expression to relate the rate of the reaction relative to concentration changes of different reactants and products?

A. $-\frac{1}{2}\Delta ClO_2/\Delta t = \Delta ClO_3^-/\Delta t$
B. $-\Delta ClO_2/\Delta t = \Delta OH^-/\Delta t$
C. $-\Delta ClO_2/\Delta t = \Delta ClO_2^-/\Delta t$
D. $-\frac{1}{2}\,\Delta OH^-/\Delta t = \Delta ClO_2^-/\Delta t$
E. $\Delta ClO_3^-/\Delta t = -\frac{1}{2}\,\Delta OH/\Delta t$



Answer

Chlorine dioxide (ClO_2), a yellow-green gas, which dissolves in water, is used as a disinfectant in some municipal water-treatment plants. It destroys the covid-19 virus. In a basic aqueous solution, it produces chlorate ion, ClO_3^-, and chlorite ion, ClO_2^-:

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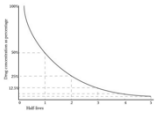
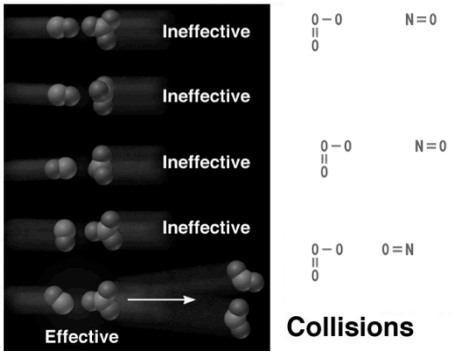
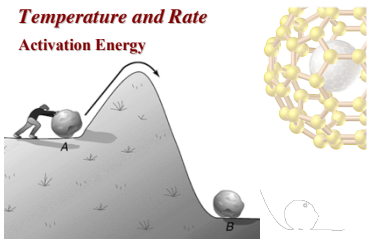


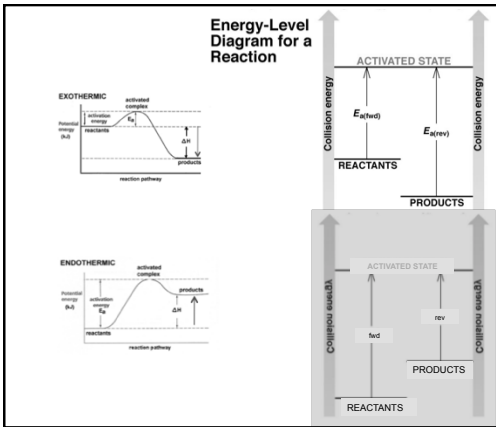
http://chemconnections.org/general/movies/Ea-1.MOV Ea-2.MOV Ea-3.MOV



Temperature: **molecules must collide with enough energy to react. (*Activation Energy, Ea*)**

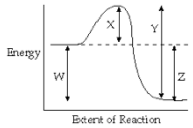
Raising the temperature increases the K.E. of the molecules, the number of collisions and the energy of the collisions.





QUESTION

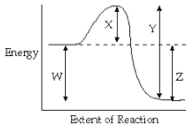
Which line in the Energy Diagram corresponds to the activation energy for the forward reaction?



A. X
B. Y
C. Z
D. W

ANSWER

Which line in the Energy Diagram corresponds to the activation energy for the reverse reaction?



A. X
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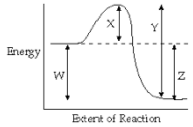
C. Z
D. W

QUESTION

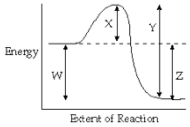
Which line in the Energy Diagram corresponds to the activation energy for the reverse reaction?



A. X
B. Y
C. Z
D. W

ANSWER

Which line in the Energy Diagram corresponds to the activation energy for the reverse reaction?



A. X
B. Y
C. Z
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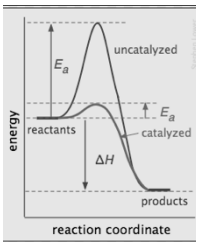
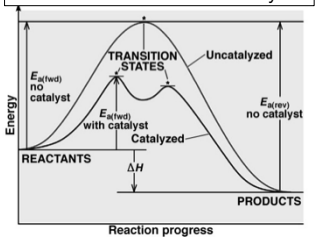
Catalysts

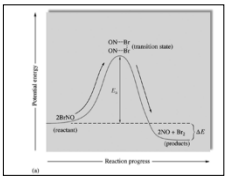
Alternative Reaction Pathways





•Catalysts increase reaction rates by lowering the Energy of Activation E_a vs E_a
•Catalysts are not consumed in chemical reactions

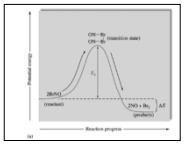
QUESTION



Which of the following is a correct conclusion based on the information presented in this figure?

A. The forward reaction is endothermic.
B. The activation energy for the forward reaction is less than the activation energy of the reverse reaction.
C. The transition state is at a lower energy than the products.
D. The energy of the reactants represents a lower energy level than both the transition state and the products.
E. A catalyst increases the energy of the transition state.

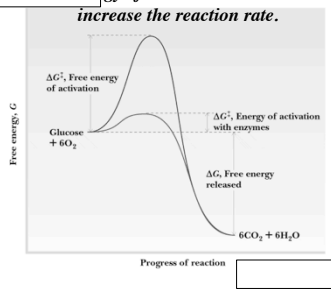
ANSWER



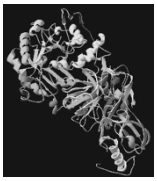
A. The forward reaction is endothermic.
B. The activation energy for the forward reaction is less than the activation energy of the reverse reaction.
C. The transition state is at a lower energy than the products.
D. The energy of the reactants represents a lower energy level than both the transition state and the products.
E. A catalyst increases the energy of the transition state.

Enzymes Catalytic Power

All catalysts: biological (enzymes) & non-biological, lower the Energy of Activation and dramatically increase the reaction rate.



Enzymes Catalytic Power



- Enzymes can accelerate reactions as much as 10^{16} times over uncatalyzed rates, i.e., 10,000,000 billion times!
- Urease: (Found in bacteria, yeast & higher plants)
  - Breaks down urea into ammonia, CO_2 and releases energy.
  - Catalyzed rate: 3 x 10^4/sec
  - Uncatalyzed rate: 3 x 10^{-10}/sec
  - Relative difference is 1 x 10^{14} (100,000 billion times)

Catalytic Differences

- https://www.youtube.com/watch?v=Ta4DomSDzF8
- https://www.youtube.com/watch?v=3Tn-7JcZJuQ

$H_2O_2\,(aq) + I^-\,(aq) \rightarrow H_2O\,(l) + IO^-\,(aq)$

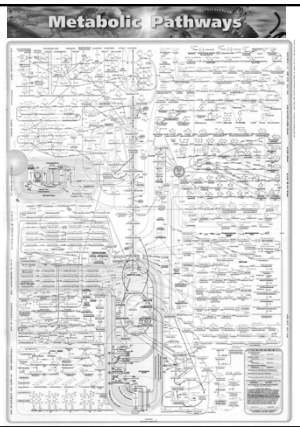
$IO^-\,(aq) + H_2O_2\,(aq) \rightarrow H_2O\,(l) + O_2\,(g) + I^-\,(aq)$

Overall Reaction: $2\,H_2O_2\,(aq) \rightarrow 2\,H_2O\,(l) + O_2\,(g)$

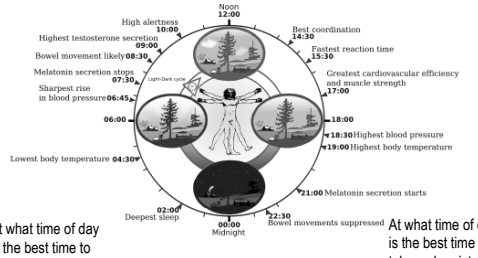
- https://www.youtube.com/watch?v=r9LItsBy1g4

Human Metabolism

Defined by enzymes: globular proteins that catalyze all reactions & processes in human chemical biology



Human Circadian Rhythm & Oscillating Chemical Reactions



At what time of day is the best time to work out with dead weights?

~4:00 – 5:00 PM

At what time of day is the best time to take a chemistry exam?

~10:00 AM

http://www.sciencedirect.com/science/article/pii/0021870765900869

Summary

Important Factors that Effect Reaction Rates

1) *Concentration:* molecules must physically *interact* (collide) in order to react.

The higher the concentration, the higher number of interactions/collisions

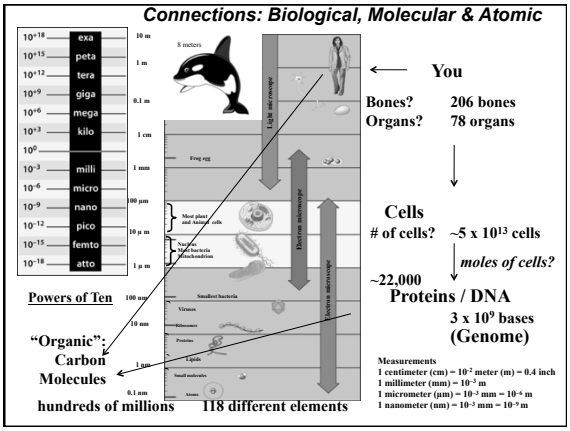
2) *Physical state:* molecules must physically mix in order to collide.

The physical state (solid, liquid, gas) will affect frequency of as well as the physical size of droplets (liquid) or particles in the case of solids. (heterogeneous vs. homogeneous)

3) *Temperature:* molecules must interact/collide with enough energy to react. (*Activation Energy, Ea*)

Raising the temperature increases the K.E. of the molecules, the number of collisions and the energy of the collisions. Relative shapes are very important. (***Catalysts lower the Activation Energy, E_a***)

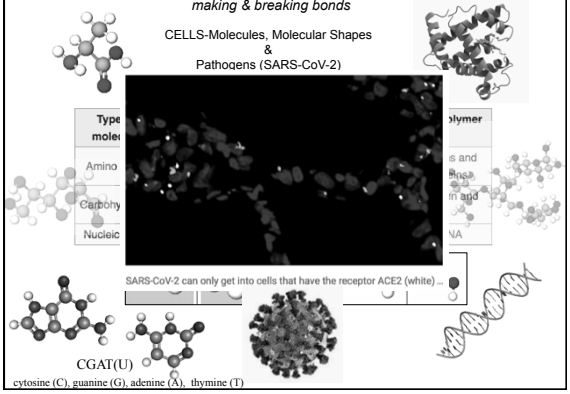
Connections: Biological, Molecular & Atomic



Enzymes, Metabolism & Infections

making & breaking bonds

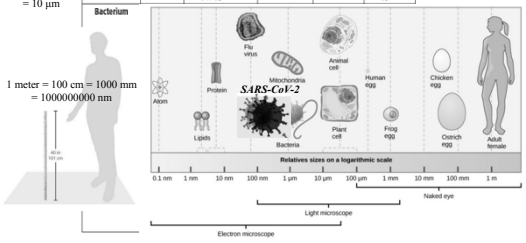
CELLS-Molecules, Molecular Shapes
&
Pathogens (SARS-CoV-2)



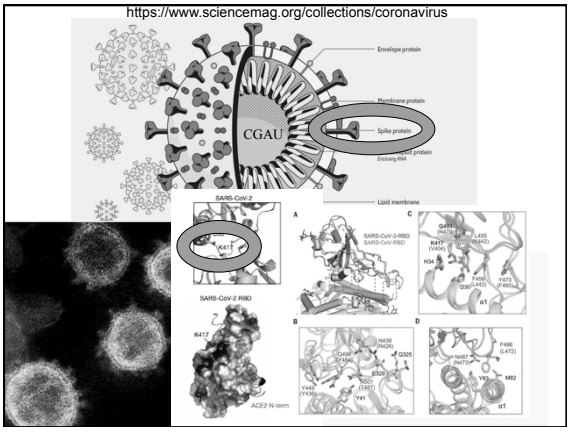
Mathematics & Powers of 10

Size, Measurement & Scale

Biological Structure	Actual Diameter (in Meters)	Size Relative to Cell	Object Used to Model Biological structure	Measured Size of Model Object	Size Relative to Model Cell (the Room)
Cell	1×10^{-5}	$\frac{1 \times 10^{-5}}{1 \times 10^{-5}} = 1$	Room	10 meters	$\frac{10}{10} = 1$
Bacterium					

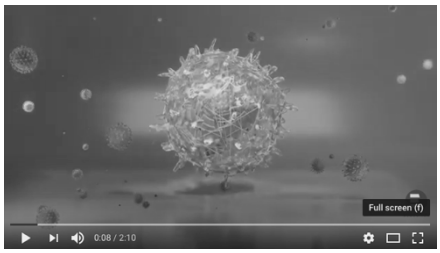


https://www.sciencemag.org/collections/coronavirus



https://www.nature.com/articles/s41586-020-2180-5

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7164635/



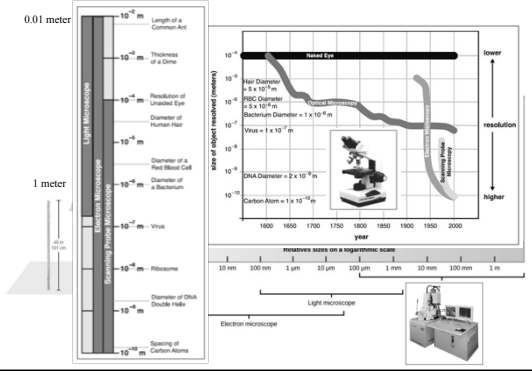
https://www.youtube.com/watch?v=D9tTi-CDjDU

https://www.nature.com/articles/s41586-020-2180-5

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7164635/

https://www.youtube.com/watch?v=j4Xiow30bGo

Size, Measurement & Scale



Mathematics & Powers of 10

Size, Measurement & Scale

Mathematics & Powers of 10

Size, Measurement & Scale

May 12, 2020

Mathematics & Powers of 10

Size, Measurement & Scale

November 13, 2020