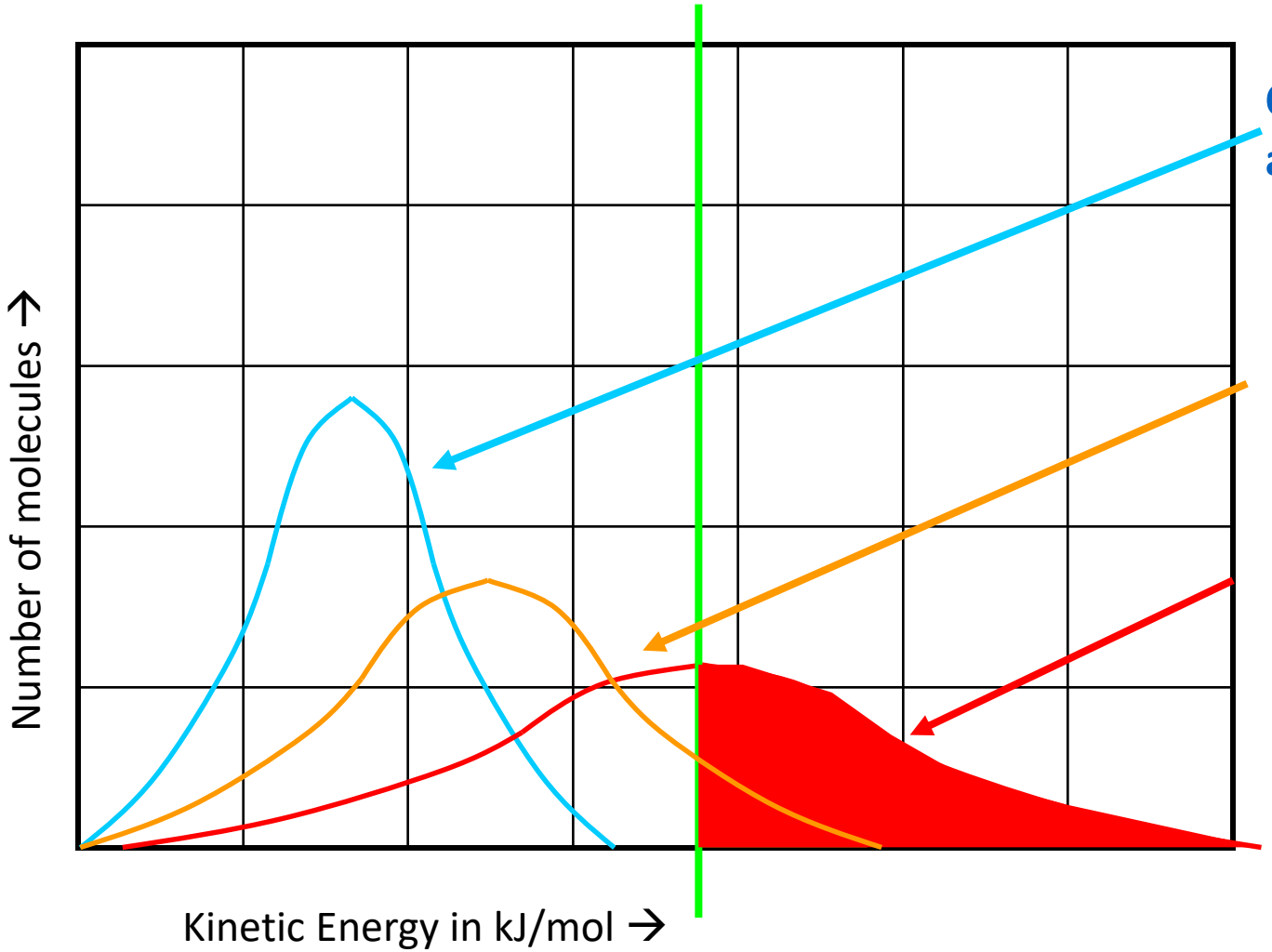
Reaction Rates

Chapters 8-10

Effect of Temperature on distribution curve



Cold: no molecules reach activation energy

Warmer: some molecules reach activation energy

Hot: many molecules reach activation energy

Factors affecting rxn rate:

Please write

1. **Temperature:**

   ↑ T = more molecules are moving faster

   = more likely that the collisions reach E_a

   = higher rate of rxn (rxn occurs more often)

2. **Concentration:**

   [↑] = collisions happen more often.

   = more likely to have a successful collision.

   = higher rate

3. **Bond strength:**

   stronger bonds = higher E_a

   = less likely to have a successful collision.

   = slower rate

Factors affecting rxn rate:

Please write

4. **Particle size:**

larger = more likely to collide

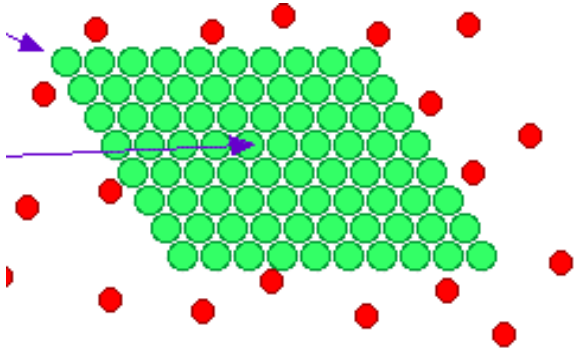
= ↑ rate of rxn

5. **Surface area:**

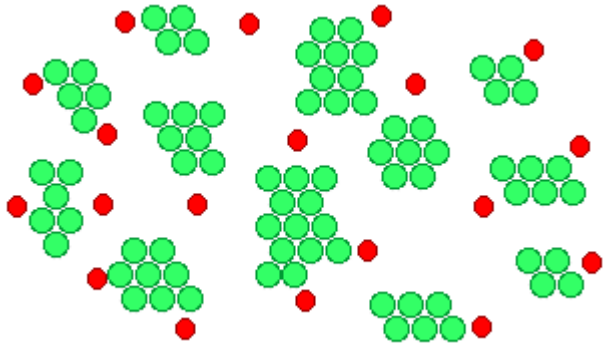
↑ SA = larger exposed area for collisions to occur.

= ↑ rate of rxn

eg. rusting



vs



6. **Catalyst:**

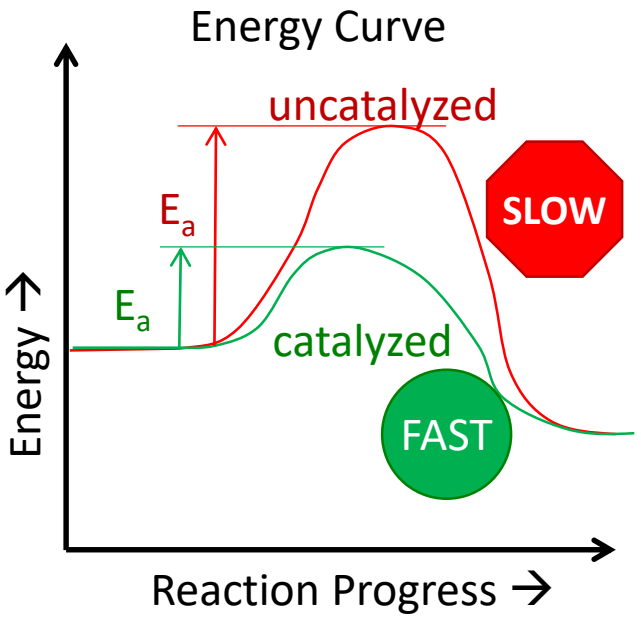
lowers E_a = collisions are more likely to be effective

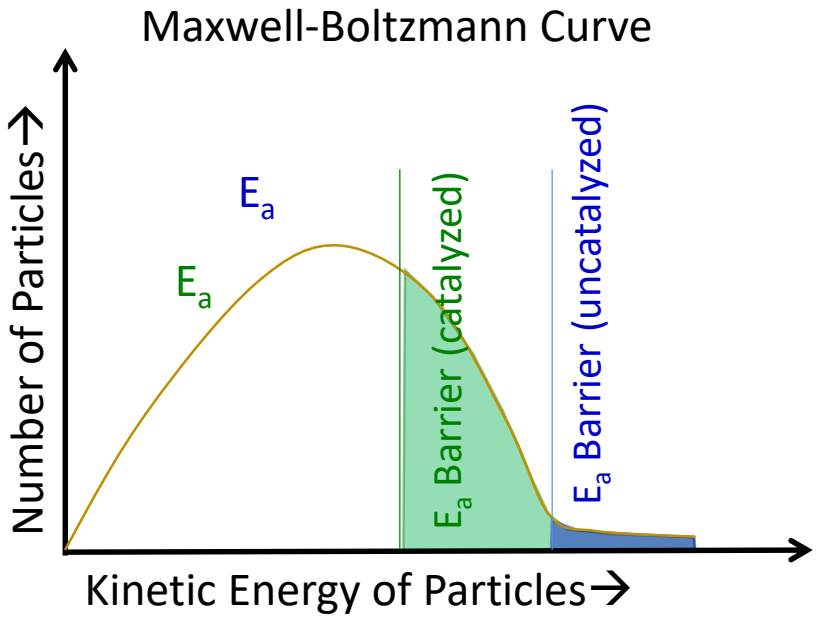
speeds up rxn without being consumed in the process

(inhibitors slow down or stop rxns)

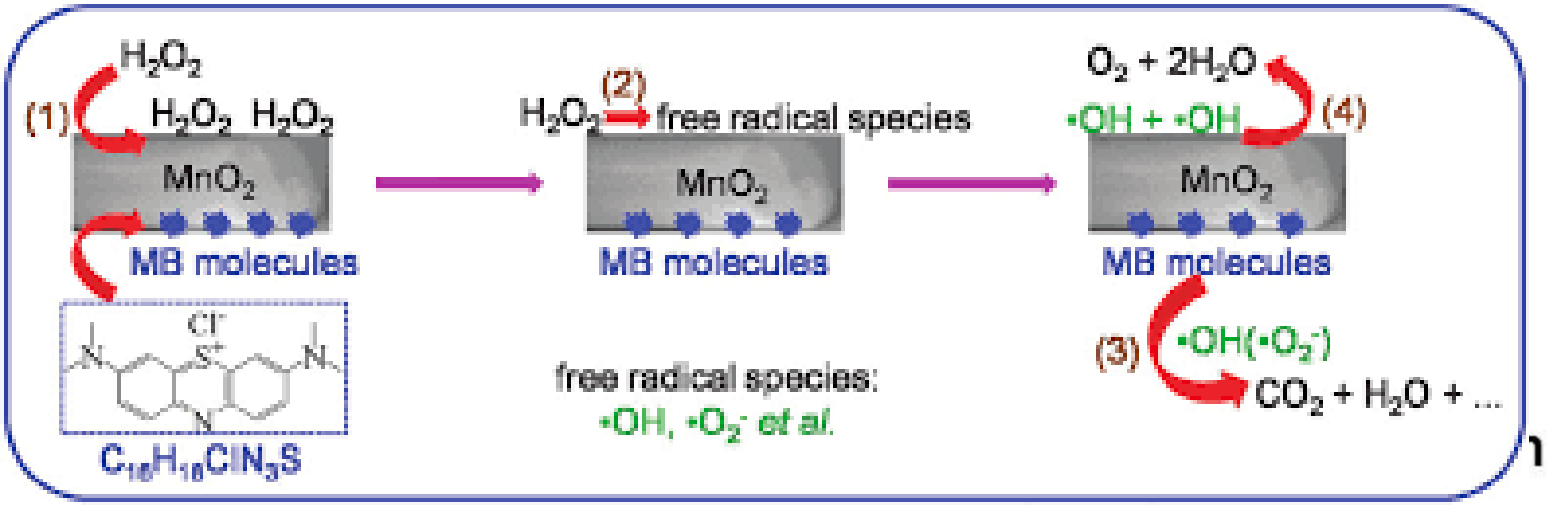
How Do Catalysts Work?

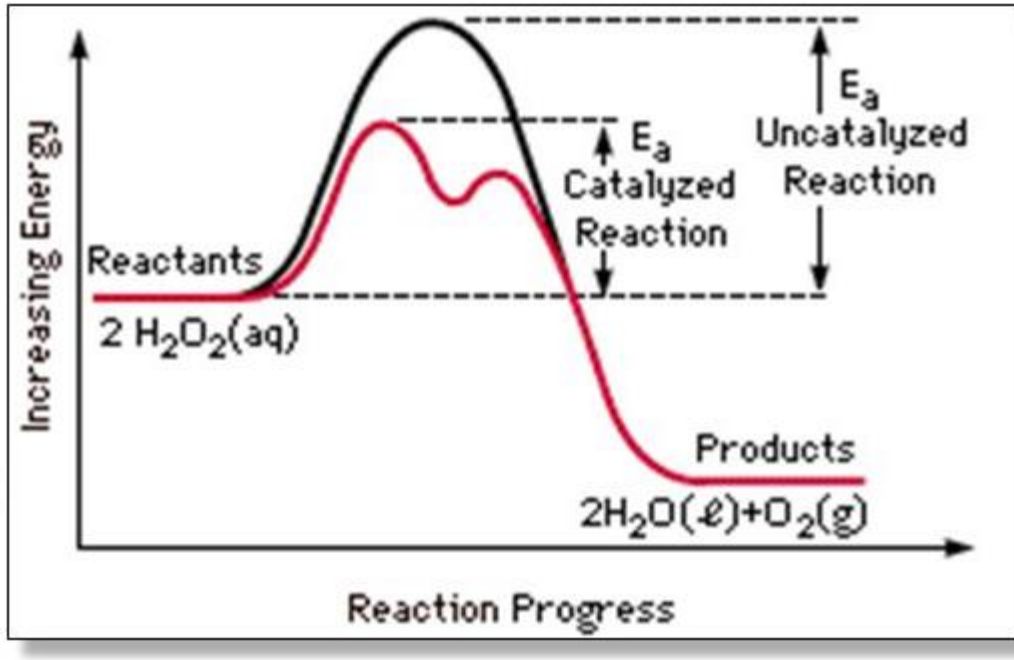
- lowering the activation energy (E_a) of a reaction.
- This causes more of the collisions to become effective.

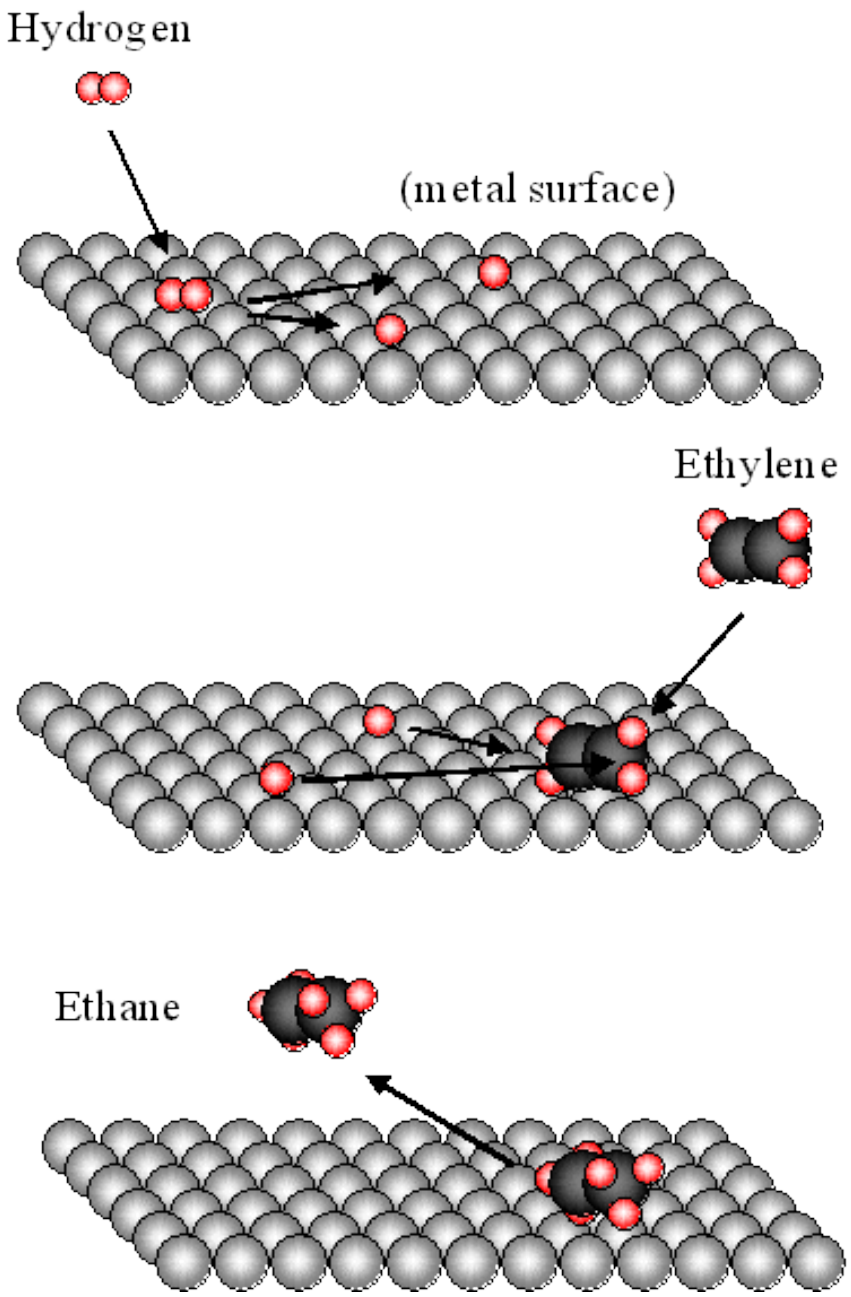


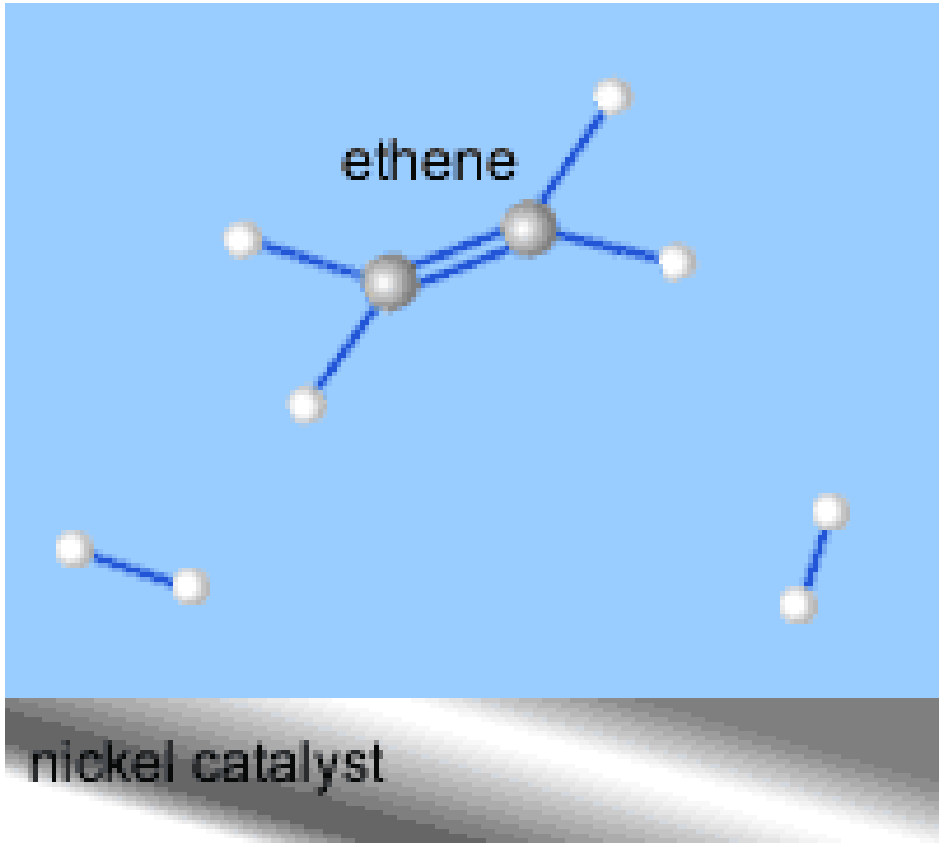


$$2\,H_2O_2 \rightarrow 2\,H_2O + O_2$$





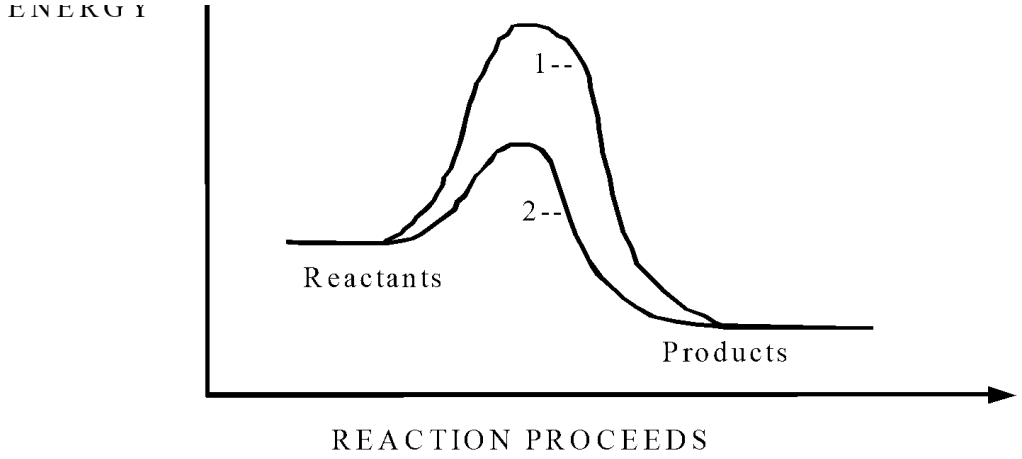

Hydrogen
(metal surface)
Ethylene
Ethane


ethene
nickel catalyst

Example:

Curves 1 and 2 on the graph below represent energy pathways for the same chemical reaction.

The reaction rate is faster for pathway number 2.



Which factor is responsible for curve 2?

A) Increase in Temp

C) Decrease in Concentration

B) Increase in SA

D) Presence of Catalyst

Example:

When you light a fire you use paper and kindling wood rather than trying to light a log with a match.

Use the collision theory to explain why.

Kindling has a greater surface area than a log

Increase SA = more area for collisions

More collisions = faster rate
b/c reach E_A sooner

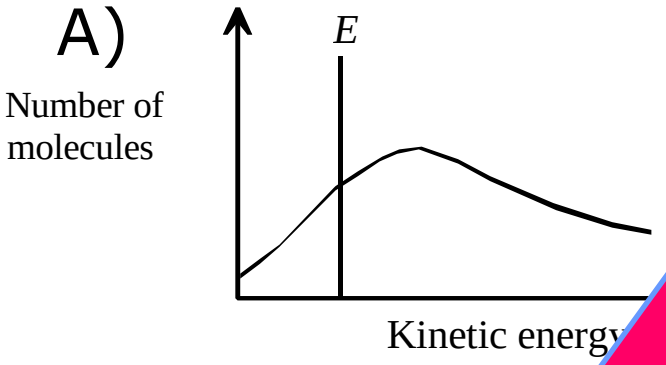
?

Example:

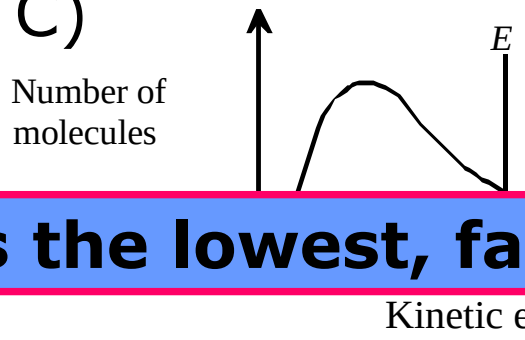
The four graphs below represent the number of molecules of reactants as a function of their kinetic energy.

Which graph represents the **fastest** reaction?

A)

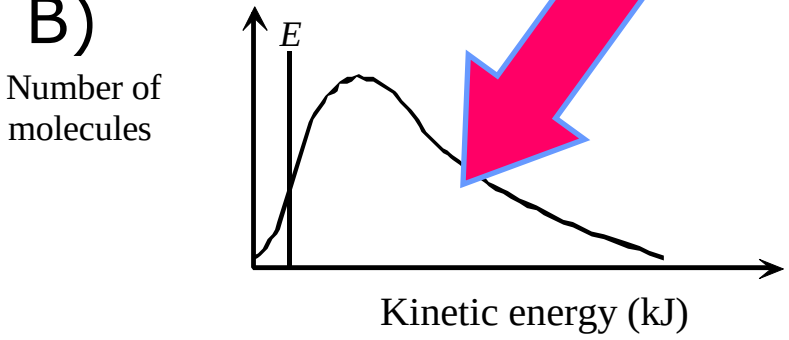


C)

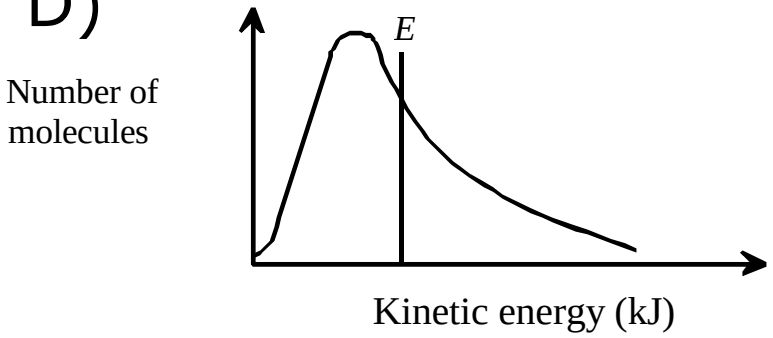


E_A is the lowest, fastest!

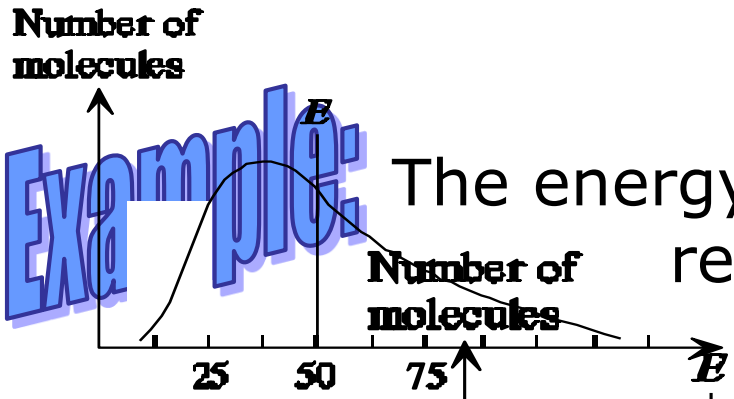
B)



D)



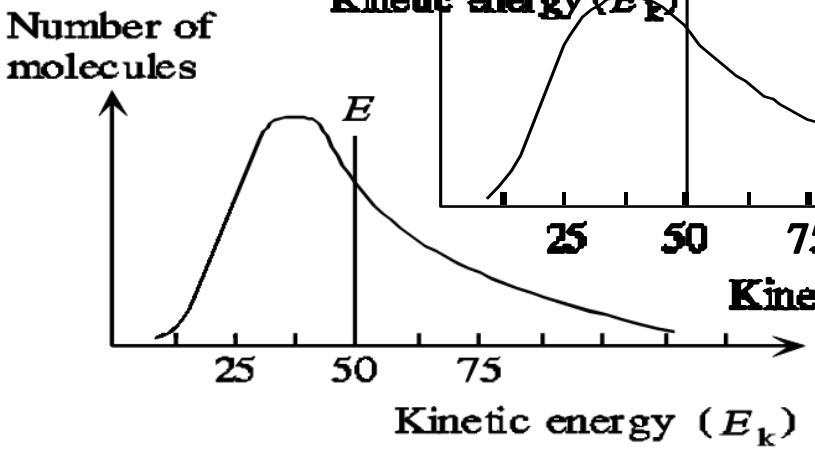
Example: The energy distribution graph for a given reaction is shown below

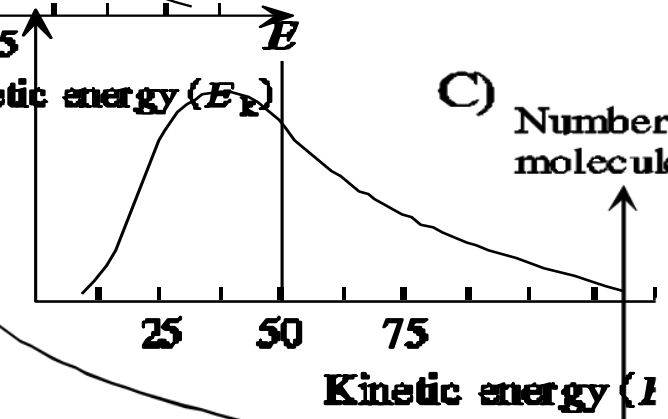


Which graph below shows t
inc
temperature?

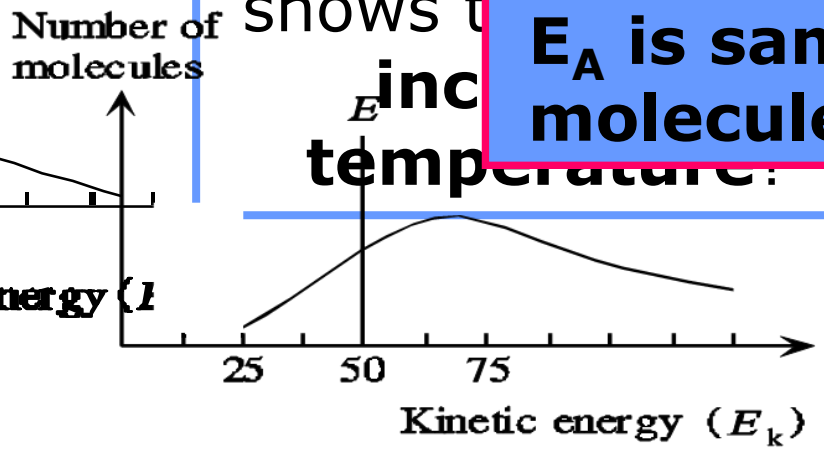
E_A is same, but less molecules below E_A

A)

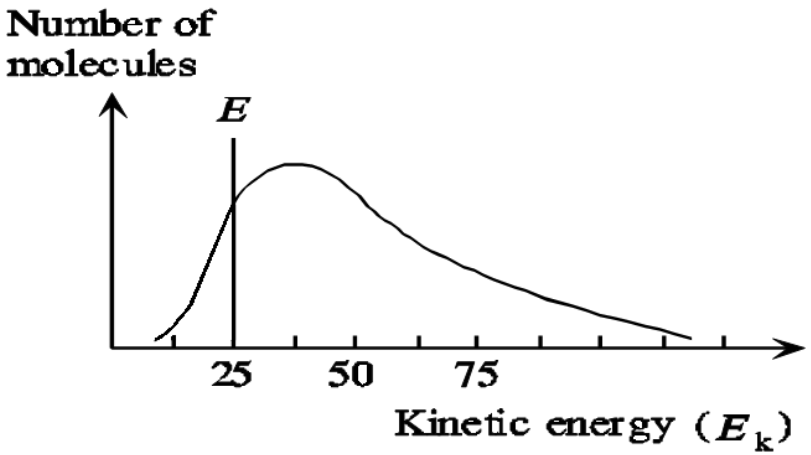




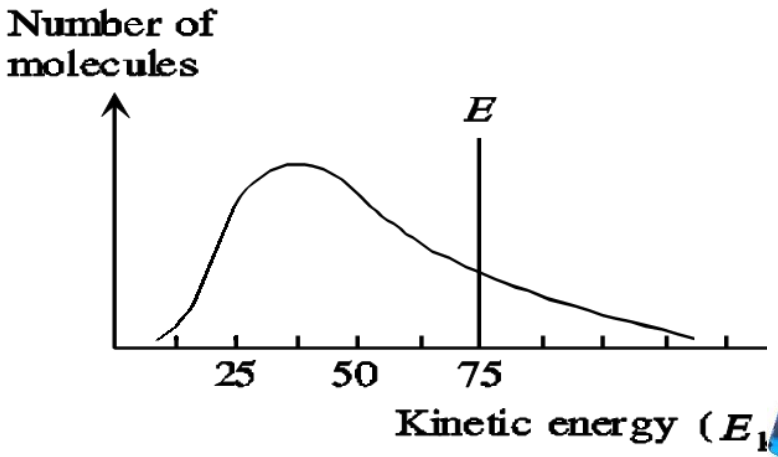
C)



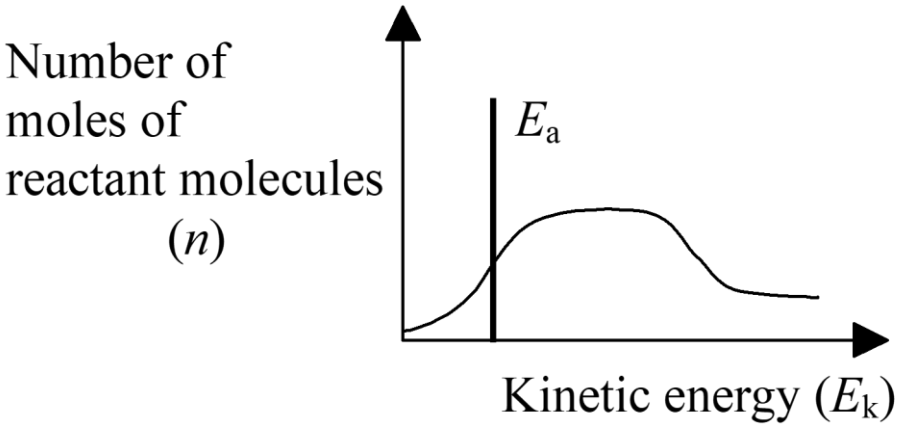
B)



D)



Old Exam Ques:



The spontaneous reaction of a solid piece of P_4 with O_2 in air has an activation energy of 30 kJ/mol and is represented by the following equation.

$$P_4(s) + 5\ O_2(g) \rightarrow P_4O_{10}(s) \qquad \Delta H = -700\ \text{kJ/mol}$$

Here is a sketch of the kinetic energy distribution curve that corresponds to this reaction at 20°C and 101 kPa.

Below is a list of 5 changes in conditions, along with 5 graphs. Which graph best corresponds to each change in conditions below?

Changes in conditions:

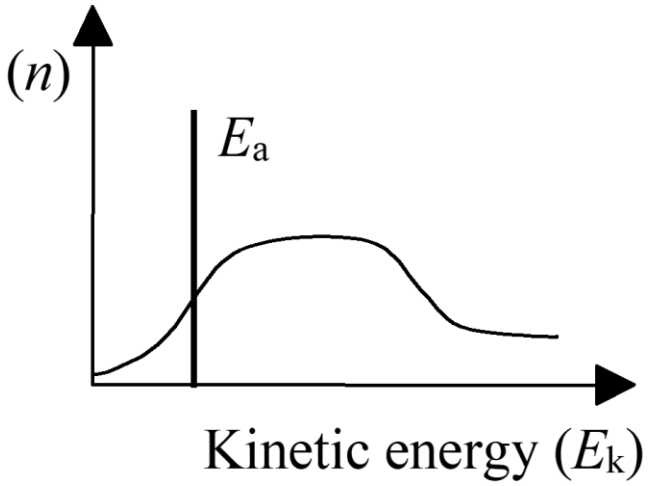
1. The $[O_2]$is increased

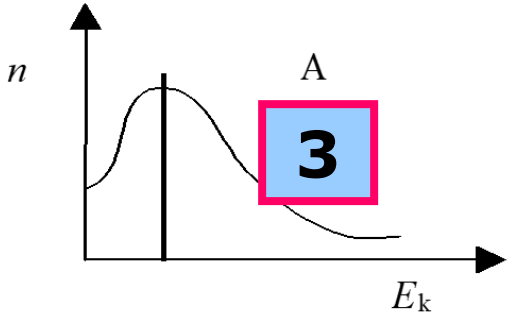
2. An inhibitor is added

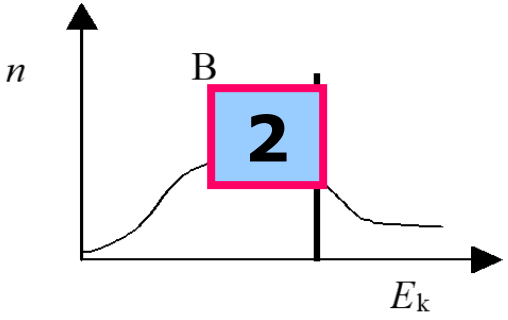
3. The temp is lowered

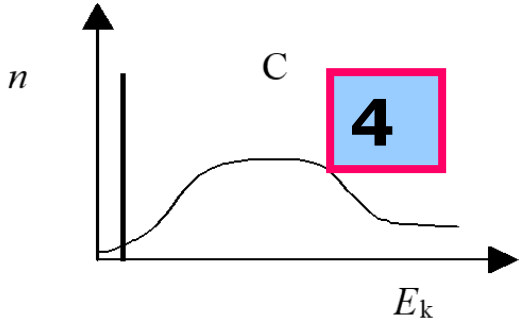
4. A catalyst is added

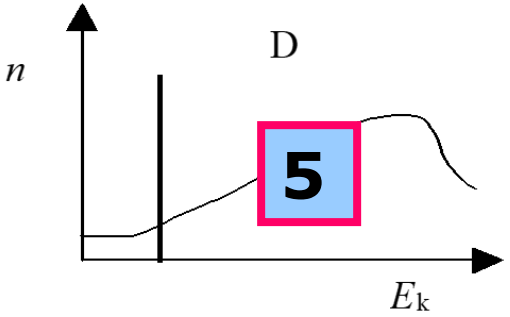
5. The temp is raised

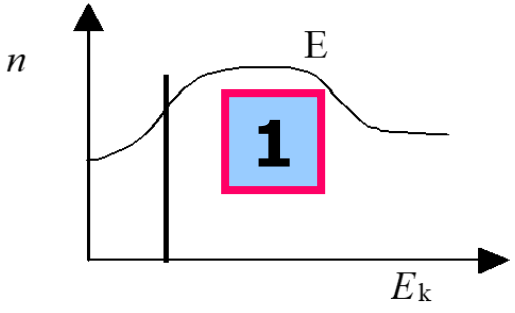


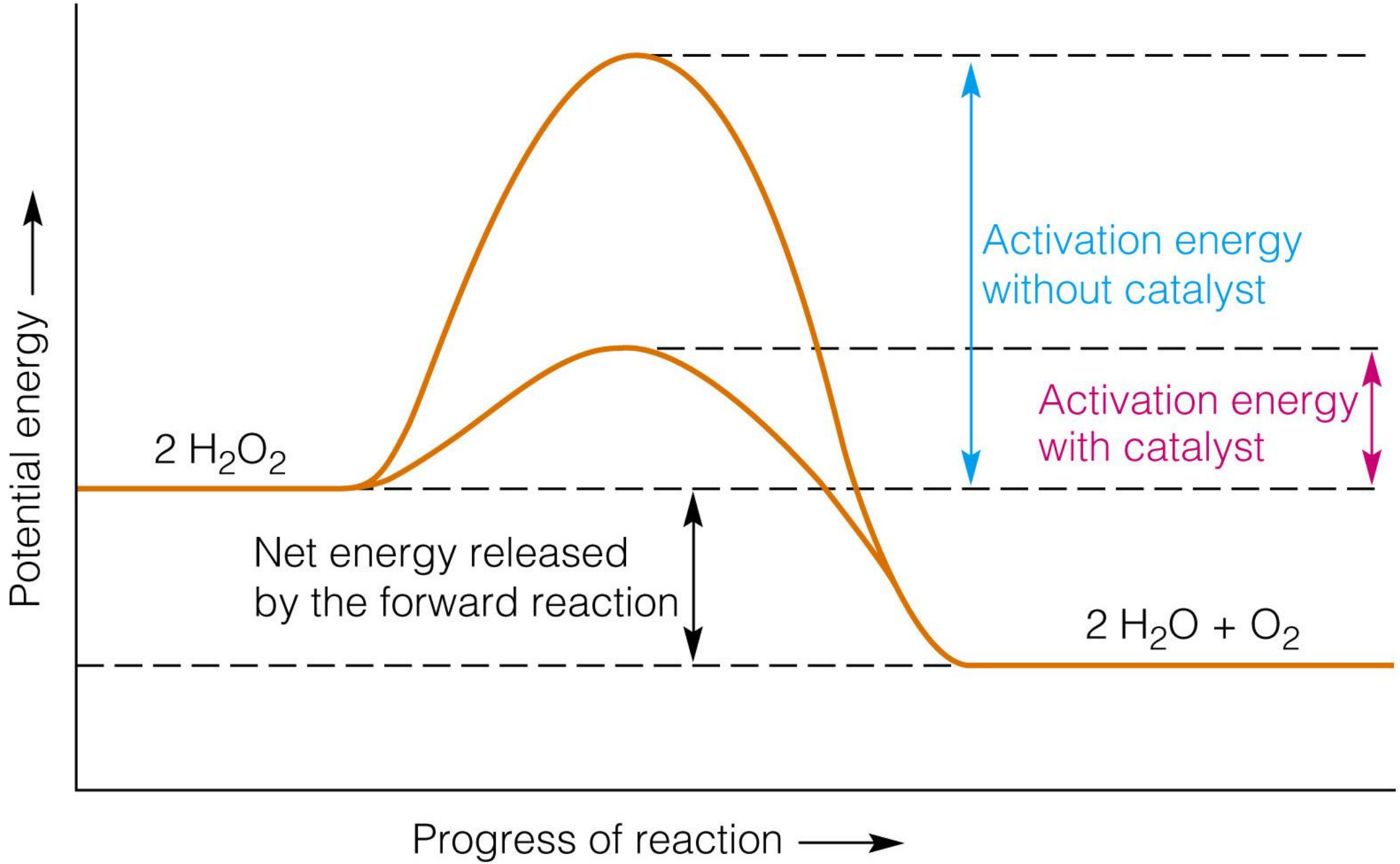








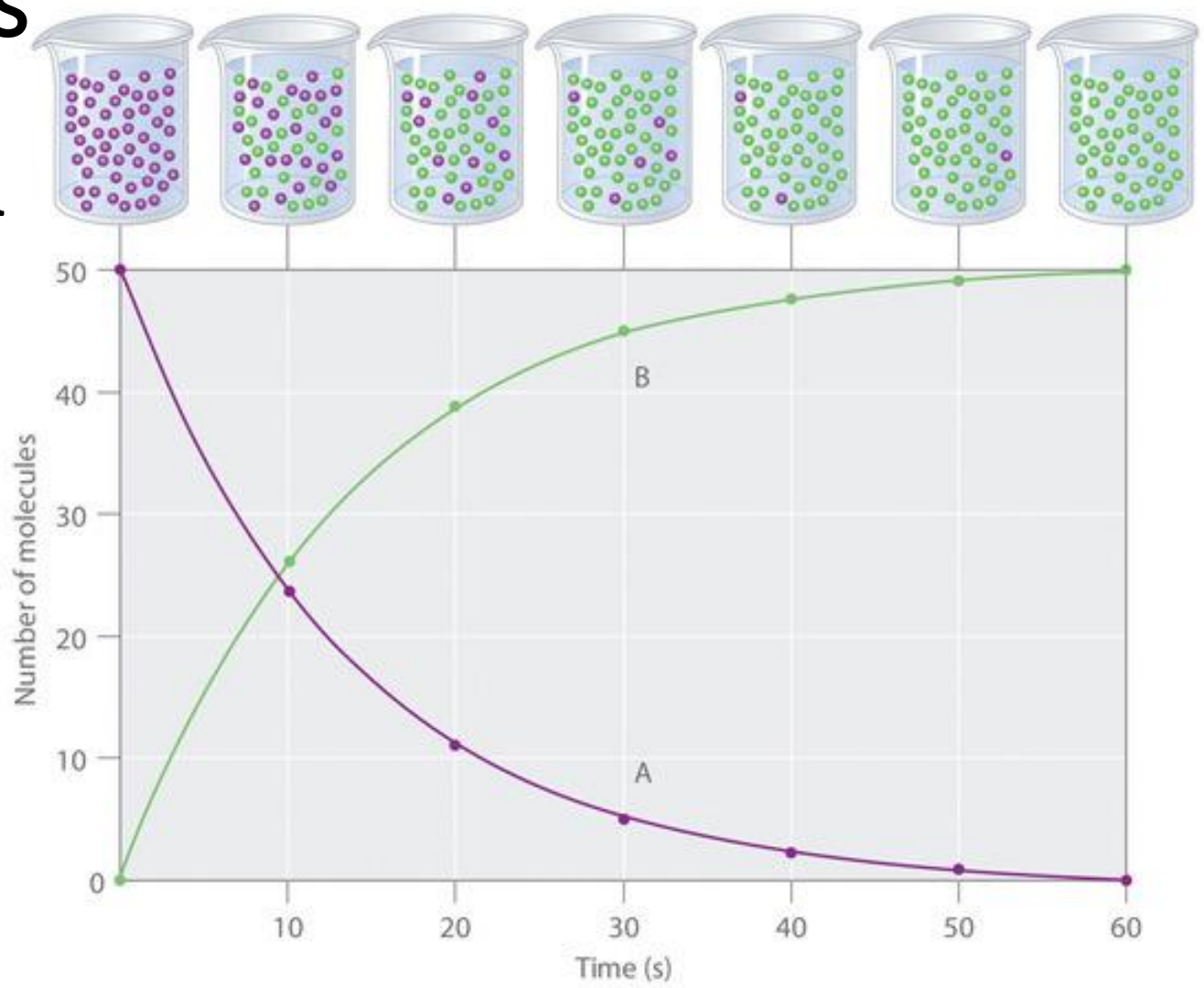



Potential energy
Activation energy
without catalyst
Activation energy
with catalyst
2 H_2O_2
Net energy released
by the forward reaction
2 H_2O + O_2
Progress of reaction

Graph of Reaction Progress

- The amount of **product** increases & the amount of **reactant** decreases.

- The reaction starts off quickly & then slows down.

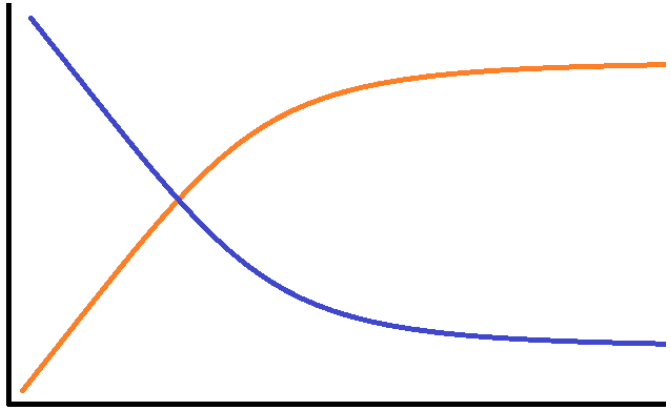


Reaction rates

Please write

- The rxn rate is not constant! (because the reactants are being used up!)
- But … for some period of time the rate **IS** constant.
- $rate = \frac{\Delta[products] \; or \; \Delta[reactants]}{\Delta time}$
- [ ] = concentration measured in Molarity

  1 M = 1 mol / L (a.k.a molar concentration)
- [↑] = increased concentration = ↑ rate why ???



eg. $H_2 + I_2 \rightarrow 2\,HI$

rate α $[H_2]$

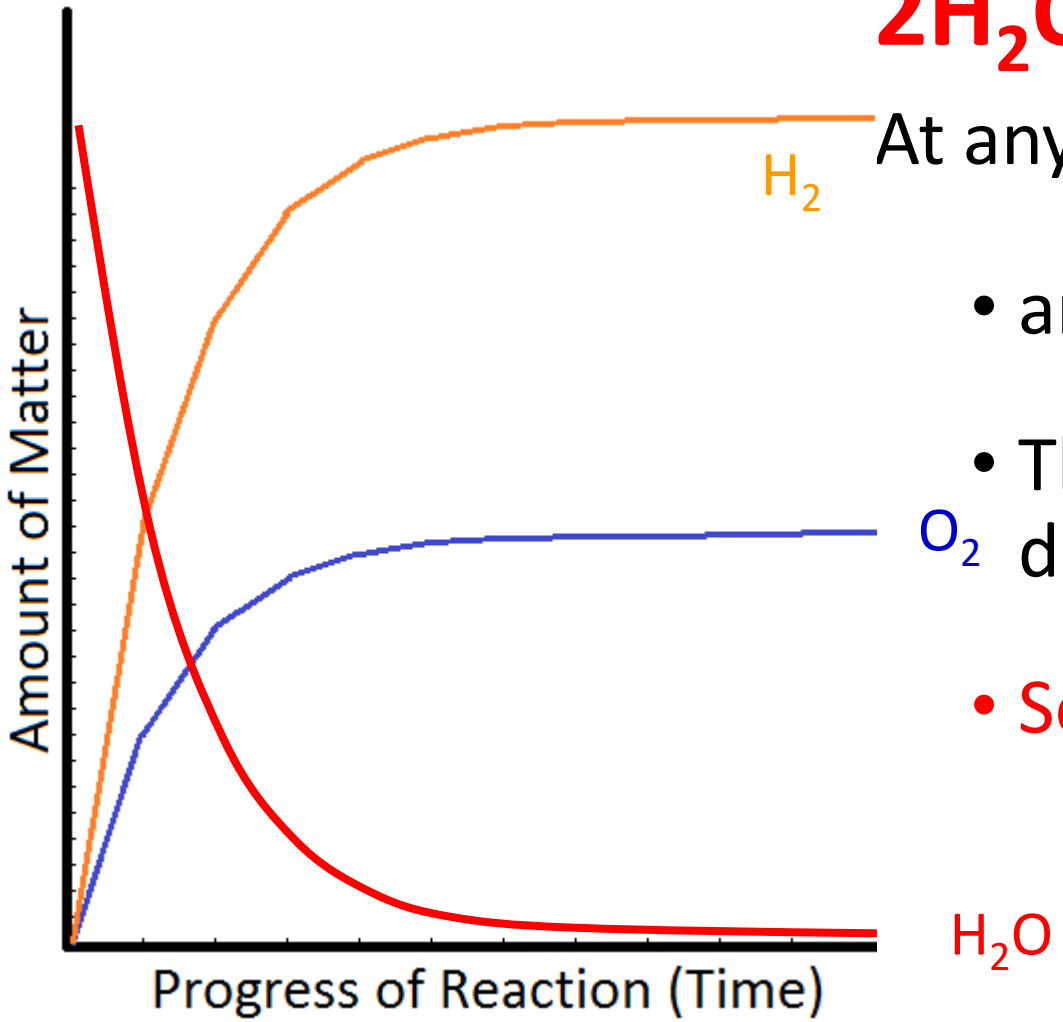
rate α $[I_2]$

rate α $[H_2][I_2]$

Graph of a rxn with 2 products

Water vapour (steam) is decomposed into hydrogen and oxygen gas.

$$2H_2O \rightarrow 2H_2 + O_2$$



At any given point on the graph:

- amount of H_2 produced = 2bl amount of O_2.
- This means that the rate of H_2 production is double the rate of O_2 production.
- So… the rate corresponds to the molar ratios!

Rxn: aA + bB → cC + dD rate α $[A]^a [B]^b$

Please write

- Rate equation: $\boxed{\text{Rate} = k [A]^a [B]^b}$

Coefficients become the exponents

Rate constant (k):

- Slope of the constant rate
- Influenced by P, T, [ ], SA etc
- determined experimentally for each rxn at given temp
- Large k = fast reaction
- Small k = slow reaction

Please note!
This rate equation only works for bi-molecular rxns (one E_a).

Ex #1

$NO_2(g) + O_3(g) \rightarrow NO_3(g) + O_2(g)$

What is the rate equation for the formation of $NO_3(g)$ and $O_2(g)$?

Rate = k $[NO_2][O_3]$

If the initial $[NO_{2(g)}]$ & $[O_{3(g)}]$ is 1.0M, what would happen to the **rate** if we increased $[NO_2]$ to 2.0M?

Rate = k [1][1]

Rate = 1k

Rate = k [2][1]

Rate = 2k

Rate doubles!

Ex #2

$$2NO + O_2 \rightarrow 2NO_2$$

What is the rate equation for the formation of NO_2? Rate = k $[NO]^2[O_2]$

If the initial concentration of both reactants is 1.0M, what would happen to the **rate** if we increased the $[O_2]$ to 2.0M?

Rate = k $[1]^2[1]$

= 1k

Rate = k $[1]^2[2]$

= 2k

Rate doubles!

If the [NO] was 2.0M?

Rate = k $[2]^2[1]$

= 4k

Rate quadruples!

STOP!

- Do Chemical Kinetics II sheet

Summary of rates (so far) ….

- **The rate of a certain rxn changes when one changes the:**
  1. **Temperature,**
  2. **Concentration (& Pressure for gases),**
  3. **Bond strength & particle size,**
  4. **Surface area**
  5. **Presence of a catalyst.**

Please write

$$4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$$

- The rate equation (a.k.a. rate law) is an expression using [reactants].
  - **Rate = k $[A]^a$ $[B]^b$ becomes Rate = k $[NH_3]^4$ $[O_2]^5$**

- The "rxn rate" is tells you how quickly <u>each</u> reactant is used up.

  or how quickly each product is produced.

$$rate = \frac{\Delta[products] \text{ or } \Delta[reactants]}{\Delta time}$$

  - A mole ratio can be used to find the rate at which the other molecules are used or formed

    Ex. If NO is formed at a rate of 4.1 mol/s…

    a) how fast is NH_3 used?

    - 4.1 mol/s of NH_3

    b) how fast is H_2O produced?

    4.1 mol/s NO x 6/4 = 6.2 mol/s H_2O

Worksheet –

- Do Chemical Kinetics III sheet