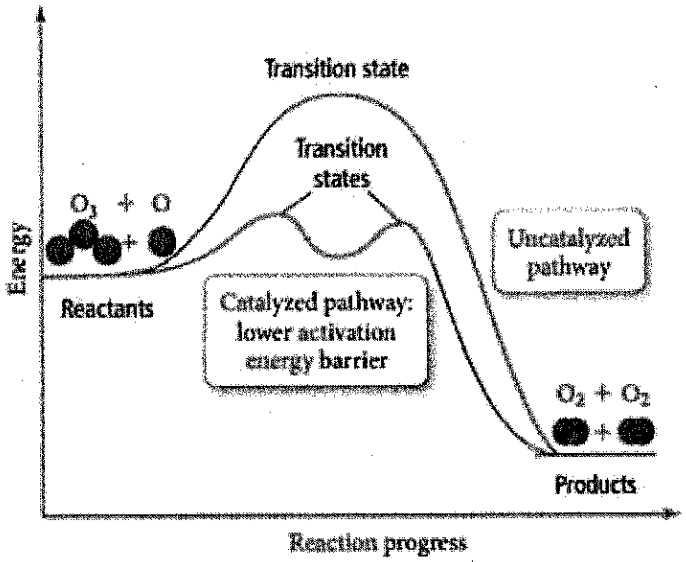
Catalysts

Catalyst: something that increases the rate of a reaction without being consumed in the reaction.

- Provides a surface or better orientation (an alternate pathway) for reaction, increasing # of effective collisions
- Usually replaces 1 high activation energy step with 2 or more lower activation energy steps (you need to draw a new energy diagram for catalyzed reaction)
- Is consumed in an early mechanism step and then produced in a later step.
- Does not change thermodynamics, only kinetics! (can speed up a reaction, but ΔH is the same)

Energy Diagram for Catalyzed and Uncatalyzed Pathways



Mechanism without catalyst:

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

Mechanism with catalyst:

step 1: $Cl(g) + O_3(g) \rightarrow O_2(g) + ClO(g)$ fast

step 2: $ClO(g) + O(g) \rightarrow O_2(g) + Cl(g)$ slow

Catalysts vs. Intermediates: two species that can appear in a reaction mechanism, but NOT in the overall reaction!

→ Both are species crossed off when summing a reaction mechanism into overall reaction

- If a species forms as a product in an earlier step and is used up as a reactant in a later step (and cancels out), it's an **intermediate**.
- If a species is used as a reactant in an earlier step and is re-formed as a product in a later step (and cancels out), it's a **catalyst**.

Let's Practice!

1. $H_2O_{2\,(aq)} + I^-_{(aq)} \rightarrow H_2O_{(l)} + IO^-_{(aq)}$ slow

   $H_2O_{2\,(aq)} + IO^-_{(aq)} \rightarrow H_2O_{(l)} + O_{2\,(g)} + I^-_{(aq)}$ fast

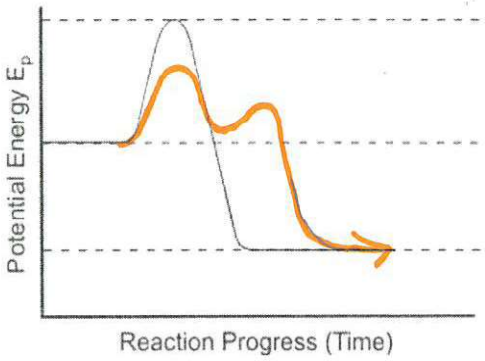
Does this reaction mechanism have an intermediate and/or catalyst? Identify and explain your classification.

IO^- is an intermediate: produced in an early step, consumed in a later step

I^- is a catalyst: consumed in an early step, produced in a later step

2. Monoxygen reacts with ozone to produce dioxygen molecules in the upper atmosphere: $O + O_3 \rightarrow 2O_2$

The potential energy diagram for this reaction is shown to the right.



a. Modify the diagram to the right to show any changes to the reaction pathway that would result for the catalyzed reaction involving these steps:

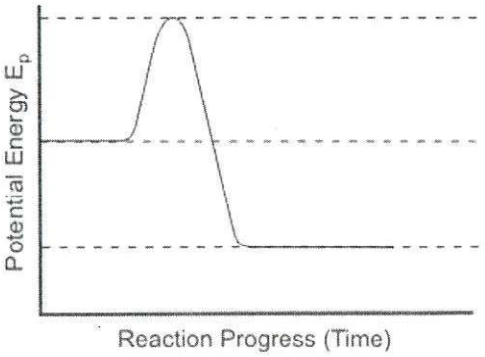
Step 1: $O_3 + NO \rightarrow NO_2 + O_2$ slow

Step 2: $NO_2 + O \rightarrow NO + O_2$ fast

in the mechanism

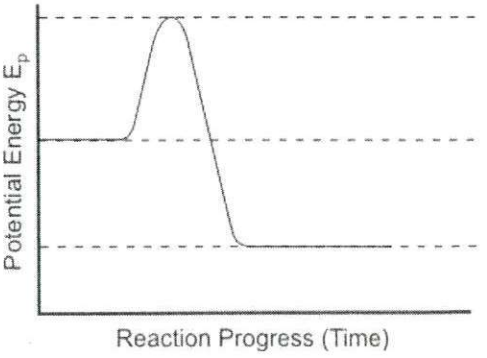
Explain your reasoning.

Catalyzed pathway will have 2 activation energies (1 for each step), both lower than uncatalyzed E_a, but the slow step (1st step) has a higher E_a than the fast step.



b. Modify the diagram to the right to show any changes to the reaction pathway that would result when the starting temperature of the reaction was doubled. Explain your reasoning.

★ no change! ↑T does not affect E_a or rxn pathway (it only ↑ # of effective collisions)



c. Modify the diagram to the right to show any changes to the reaction pathway that would result when the concentration of ozone, O_3, was decreased by a factor of 3. Explain your reasoning.

★ no change! ↓ [reactants] does not affect E_a (but it will ↓ # of effective collisions) or the rxn pathway

Multiple Choice Practice FTW!

$$4\ NH_3(g) + 5\ O_2(g) \rightarrow 4\ NO(g) + 6\ H_2O(g)$$

1. The above reaction will experience a rate increase by the addition of a catalyst such as platinum. Which of the following best explains why?

a. The catalyst causes the value for ΔG to become more negative.

b. The catalyst increases the percentage of collisions that occur at the proper orientation (sometimes) in the reactant molecules.

c. The catalyst introduces a new reaction mechanism for the reaction. ALWAYS!

d. The catalyst increases the activation energy for the reaction.