

Potential Energy Diagrams: Exothermic Reactions and Catalysts

This worksheet asks you to analyze and label a potential energy diagram for an exothermic reaction, both with and without a catalyst, in line with the energy-diagram and activation-energy outcomes of this unit ([Outcome](#), [Outcome](#)). You will also explain how a catalyst changes the reaction pathway without changing the net energy released ([Outcome](#)).

Exercises

1. Labelling the diagram

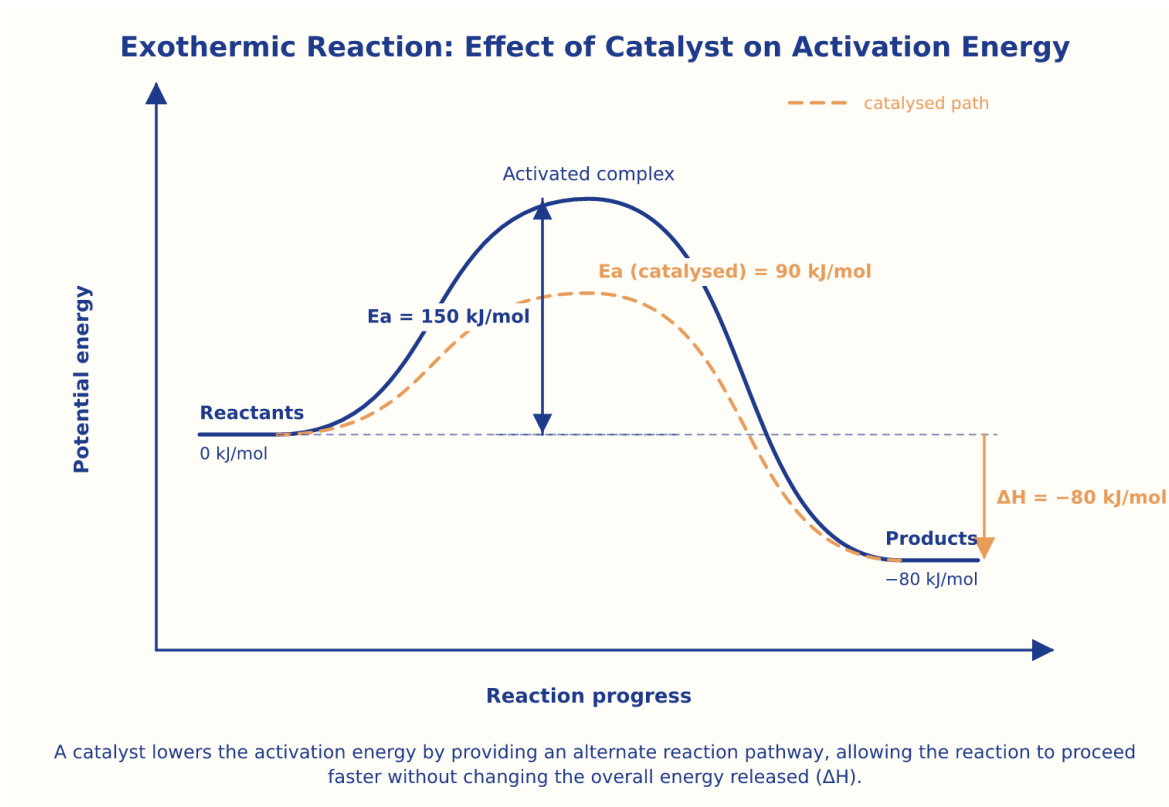


Figure 1: Potential energy diagram of an exothermic reaction: Reactants at 0 kJ/mol, Products at -80 kJ/mol, $E_a = 150$ kJ/mol, E_a (catalysed) = 90 kJ/mol, $\Delta H = -80$ kJ/mol.

The potential energy diagram above shows the reactants at 0 kJ/mol and the products at -80 kJ/mol, with an uncatalyzed activation energy (E_a) of 150 kJ/mol.

a) On the diagram, identify the position that corresponds to the activated complex (transition state). Describe its location in words.

b) State the value of ΔH for this reaction and explain, using the sign of ΔH , why this reaction is classified as exothermic.

2. Multiple choice

Which statement correctly describes the effect of a catalyst on this reaction, based on the figure (catalyzed $E_a = 90$ kJ/mol)?

- A) The catalyst lowers the activation energy and makes ΔH negative.
 B) The catalyst lowers the activation energy but does not change ΔH .
 C) The catalyst raises the activation energy but does not change ΔH .
 D) The catalyst changes ΔH , but does not affect the activation energy.

Circle your answer: A B C D

3. Calculations

Use the values given in the figure: reactants at 0 kJ/mol, products at -80 kJ/mol, uncatalyzed E_a = 150 kJ/mol, catalyzed E_a = 90 kJ/mol.

a) Calculate the activation energy for the **reverse** reaction along the uncatalyzed pathway.

Show your work:

E_a (reverse, uncatalyzed) = _____ kJ/mol

b) Calculate the activation energy for the **reverse** reaction along the catalyzed pathway.

Show your work:

E_a (reverse, catalyzed) = _____ kJ/mol

4. Matching

Match each term on the left to its correct value from the diagram.

Term	Value (kJ/mol)
1. Potential energy of reactants	_____
2. Potential energy of products	_____
3. Enthalpy change, ΔH	_____
4. Activation energy, uncatalyzed pathway	_____
5. Activation energy, catalyzed pathway	_____

Options: 0 kJ/mol, -80 kJ/mol, 90 kJ/mol, 150 kJ/mol

5. Short answer

Explain, in terms of bonds breaking and bonds forming, why the potential energy of the system rises from the reactants to the activated complex, and why it then falls to the level of the products ([Outcome](#)).

6. True or false

Circle True or False for each statement about the catalyzed and uncatalyzed pathways shown in the figure.

- a) The catalyst changes the value of ΔH for the reaction. True / False
 b) The catalyst provides an alternate reaction pathway with a lower energy barrier. True / False
 c) The reactants and products have the same potential energy values whether or not a catalyst is used. True / False

d) A lower activation energy means fewer collisions will have enough energy to react successfully, so the catalyzed reaction is slower. True / False

Answer key

- a) The activated complex sits at the peak of the curve, at 150 kJ/mol on the uncatalyzed pathway, between the reactants and the products.

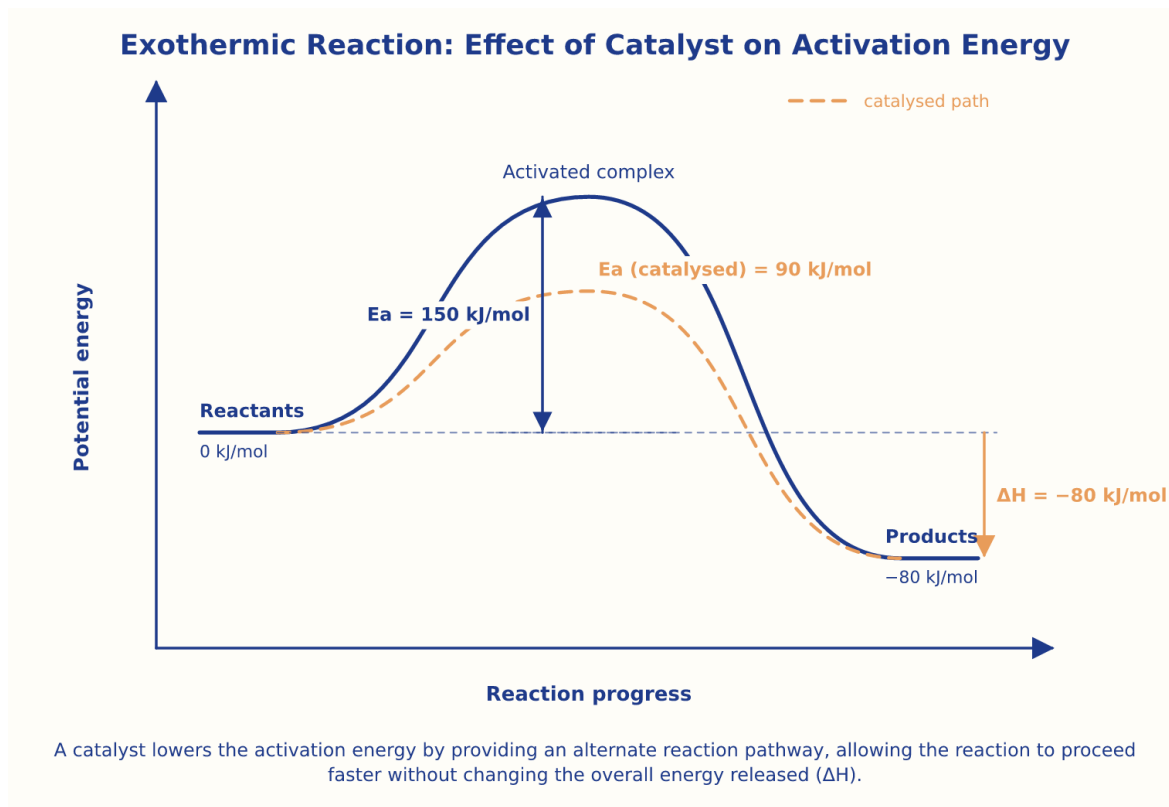


Figure 1: Potential energy diagram of an exothermic reaction: Reactants at 0 kJ/mol, Products at -80 kJ/mol, $E_a = 150$ kJ/mol, $E_a(\text{catalysed}) = 90$ kJ/mol, $\Delta H = -80$ kJ/mol.

- b) Since the products have less potential energy than the reactants, so energy is released to the surroundings, which is characteristic of an exothermic reaction ([Outcome](#)).
- B. The catalyst lowers the activation energy from 150 kJ/mol to 90 kJ/mol but the products are at -80 kJ/mol, since a catalyst changes the pathway, not the net energy of the reaction ([Outcome](#)).
- a) $E_a(\text{reverse, uncatalyzed}) = E_a(\text{forward}) - \Delta H = 150 \text{ kJ/mol} - (-80 \text{ kJ/mol}) = 230 \text{ kJ/mol}$
b) $E_a(\text{reverse, catalyzed}) = E_a(\text{forward, catalyzed}) - \Delta H = 90 \text{ kJ/mol} - (-80 \text{ kJ/mol}) = 170 \text{ kJ/mol}$
- 1: 0 kJ/mol; 2: -80 kJ/mol; 3: -80 kJ/mol; 4: 150 kJ/mol; 5: 90 kJ/mol.
- As reactant bonds break, the system absorbs energy, so potential energy rises toward the activated complex. As new product bonds form, the system releases energy, so potential energy falls toward the level of the products. Because more energy is released forming product bonds than was absorbed breaking reactant bonds, the products end up at a lower potential energy than the reactants ([Outcome](#)).
- a) False; b) True; c) True; d) False (a lower activation energy means more collisions have enough energy to react, so the catalyzed reaction is faster) ([Outcome](#)).