Warm-Up | Reaction Pathways

Endothermic and Exothermic Reactions

Endothermic reactions and processes [absorb] energy.

- $\Delta H > 0$.
- Heat is a reactant.

Exothermic reactions and processes [release] energy.

- $\Delta H < 0$.
- Heat is a product.

4

Calculating ΔH_{rxn}

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$$

$\Delta H_{f,CH_4} = -74.8\ \text{kJ/mol}$

$\Delta H_{f,CO_2} = -393.5\ \text{kJ/mol}$

$\Delta H_{f,H_2O} = -241.82\ \text{kJ/mol}$

$$\Delta H_{rxn} = \Delta H_{prod} - \Delta H_{react}$$
$$\Delta H_{prod} = (-393.5) + (-241.82) \times 2$$
$$= -877.1$$
$$\Delta H_{react} = -74.8 + 0$$
$$= -74.8$$

$$\Delta H_{rxn} = \Delta H_{prod} - \Delta H_{react}$$
$$= -877.1 - (-74.8)$$
$$= \boxed{-802.3}\ \text{kJ}$$

Notice that the total ΔH is [negative]. That means this reaction is exothermic, and it's [releasing] 802.3 kilojoules of energy.

Warm-Up | Reaction Pathways

4

Calculating ΔH_{rxn}

$$CaCO_3(s) \rightarrow CaO(s) + O_2(g)$$

$$\Delta H_{f,CaCO_3} = -1207.1\ kJ/mol$$

$$\Delta H_{f,CaO} = -635.5\ kJ/mol$$

$$\Delta H_{rxn} = \Delta H_{prod} - \Delta H_{react}$$

$$\Delta H_{prod} = (-635.5) + 0$$

$$= -635.5$$

$$\Delta H_{react} = -1207.1$$

$$\Delta H_{rxn} = \Delta H_{prod} - \Delta H_{react}$$

$$= -635.5 - (-1207.1)$$

$$= \boxed{571.6}\ kJ$$

Notice that this result is [positive], meaning this reaction is [endothermic], and it requires 571.6 kilojoules of energy.

Lesson Objectives

By the end of this lesson, you should be able to:

- Interpret reaction pathways.
- Use reaction pathway graphs to identify [exothermic] and endothermic reactions.
- Define and explain the role of the activation energy in a chemical reaction.

Science Practice: Interpret and make inferences from reaction pathway graphs.

Warm-Up | Reaction Pathways

Words to Know

Fill in this table as you work through the lesson. You may also use the glossary to help you.

activated complex	the short-lived, high-energy intermediate between reactants and products
activation energy	the minimum amount of energy needed to initiate a chemical reaction
reaction pathway graph	a diagram indicating the change in energy between reactants and products

Instruction | Reaction Pathways

Slide 1

Lesson Question

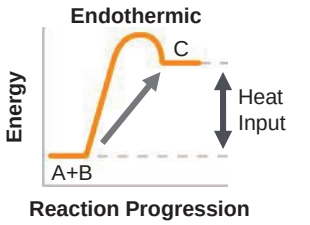
How can graphs be used to study the energy in a reaction?

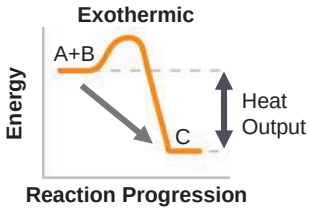
Slide 2

Reaction Pathway Graphs

Reaction pathway graph – a diagram indicating the change in [energy] between reactants and products

- Is sometimes called [potential] energy diagram
- Has energy on vertical axis
- Has reaction progression on horizontal axis
- Has reactants to the left
- Has products to the right



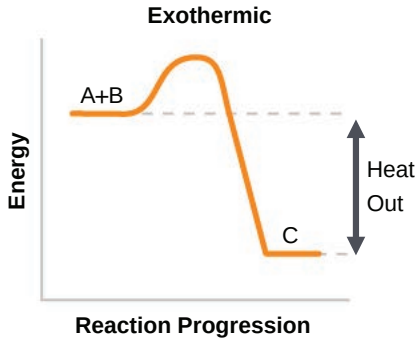


Slide 5

Exothermic Reaction Pathway

Exothermic reactions release energy.

- Reactant energy [higher] than product energy.
- Magnitude of difference indicates magnitude of ΔH_{rxn}.



Instruction | Reaction Pathways

Slide 5

Exothermic Reactions

Examples of exothermic processes:

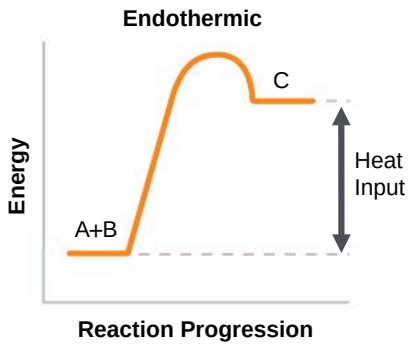
- Condensation
- Combustion
- Dissociation of strong acids
- Solidification of cement, concrete, epoxy
- Thermite reaction

Slide 7

Endothermic Reaction Pathway

Endothermic reactions absorb energy.

- Reactant energy is lower than product energy.
- Magnitude of difference indicates magnitude of ΔH_{rxn}.



Examples of endothermic processes:

- Melting
- Photosynthesis
- Many decomposition and dehydration reactions
- Dissociation of some salts

Instruction | Reaction Pathways

Slide 10

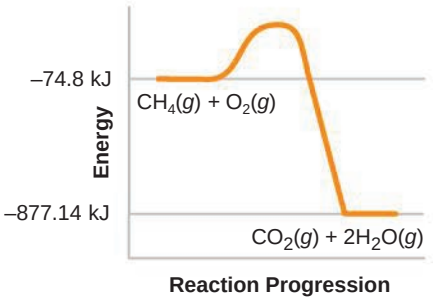
Calculating ΔH_{rxn} from a Reaction Pathway Graph

- $\Delta H_{rxn} = \Delta H_{f,products} - \Delta H_{f,reactants}$

  $= -877.14 - (-74.8)$

  $=$ [−802.3] kJ

$CH_4(g) + O_2(g) \rightarrow CO_2(g) + 2$ [H_2O] (g)



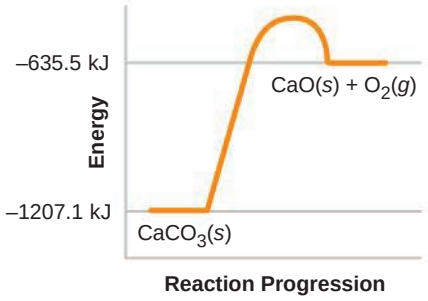
Calculating ΔH_{rxn} from a Reaction Pathway Graph

- $\Delta H_{rxn} = \Delta H_{f,products} - \Delta H_{f,reactants}$

  $= -635.5 - (1207.1)$

  $=$ [+571.6] kJ

$CaCO_3(s) \rightarrow CaO(s) + O_2(g)$

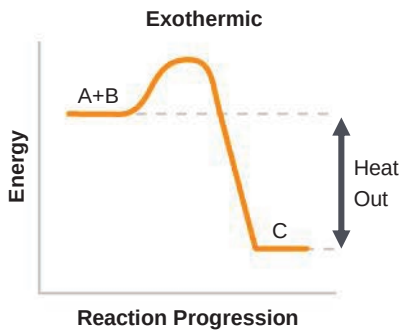


14

Activation Energy and the Activated Complex

Activation energy (E_a) – the [minimum] amount of energy needed to initiate a chemical reaction

Activated complex – the [short-lived], high-energy intermediate between reactants and products



Instruction | Reaction Pathways

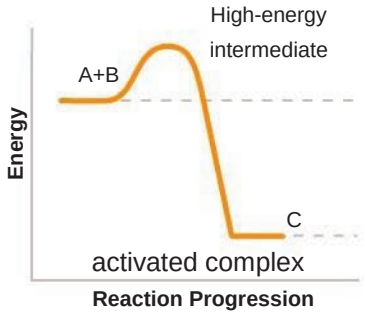
Slide 14

Dehydration of Sucrose

reactant ($C_{12}H_{22}O_{11}$)

and [catalyst] (H_2SO_4)

$C_{12}H_{22}O_{11}(s) \rightarrow 12C(s) + 11$ [H_2O] (l)

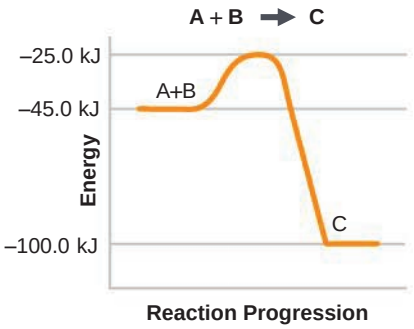


products ([C] and H_2O)

Slide 17

Calculating Activation Energy

$$E_a = H_{\text{activated complex}} - H_{\text{reactants}}$$
$$= -25.0 - (-45.0)$$
$$= \boxed{20}\ \text{kJ}$$



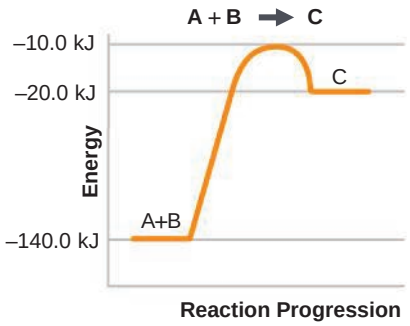
The activation energy is always [positive] because the reactants must gain some energy in order to form the [activated] complex.

Instruction | Reaction Pathways

Slide 17

Calculating Activation Energy

$$E_a = H_{\text{activated complex}} - H_{\text{reactants}}$$
$$= -10.0 - (-140.0)$$
$$= \boxed{130}\ \text{kJ}$$

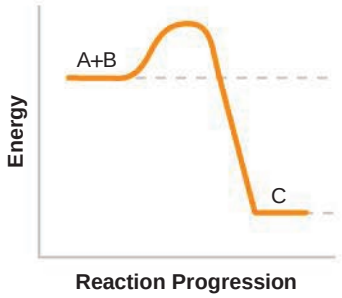


The energy of the activated complex, –10, and subtract the reactants, which is right here, –140. And we get [130] kilojoules.

Slide 20

Activation Energy and Reaction Rate

- Activation energy is the minimum energy that reactants must attain for a reaction to occur.
- Higher activation energy → more difficult to reach
- Higher activation energy → [lower] reaction rate



Summary | Reaction Pathways

Lesson Question

How can graphs be used to study the energy in a reaction?

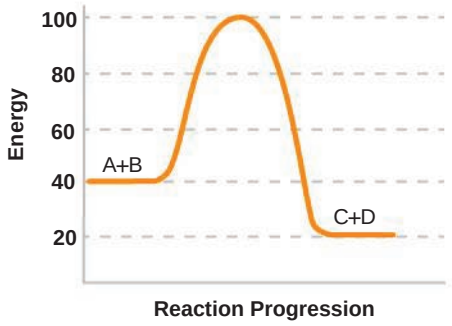
Answer

(Sample answer) Reaction pathway graphs show energy changes during the course of a chemical reaction. In an endothermic reaction, reactants have less energy than the products. In an exothermic reaction, reactants have more energy than the products. Activation energy can be calculated from a reaction pathway graph and is used to reach their activated complex.

Slide 2

Calculating ΔH_{rxn}

- Enthalpy values can be determined from reaction pathway graphs.
- The difference between the energy of the reactants and the energy of the products is the enthalpy for the reaction.



Summary | Reaction Pathways

Use this space to write any questions or thoughts about this lesson.