Energy in Reactions KEY (new)

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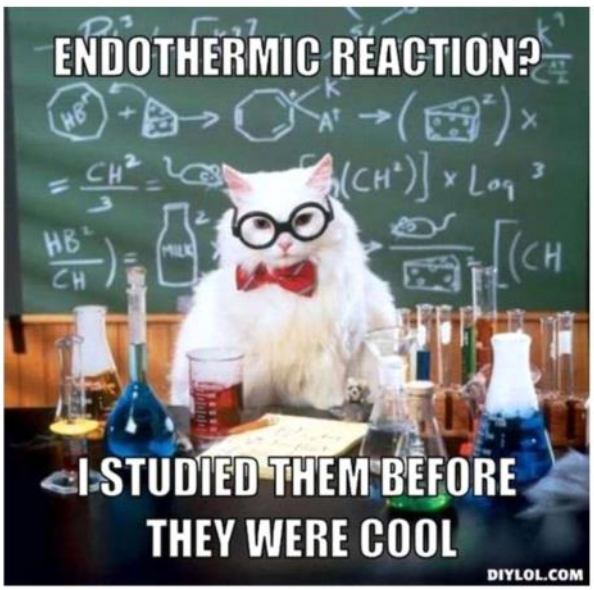
SCIENCE 10

UNIT 2: CHEMISTRY (PART 2)



BOOK 1: ENERGY CHANGES IN CHEMICAL REACTIONS

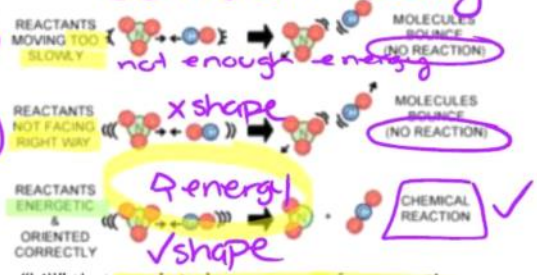
NAME: Key BLOCK: _____

1

part a) how is energy involved in chemical processes?

"collision theory"

matter and energy are continually interacting in the world around us.



For any chemical reaction to occur, the reactants must collide with the products with enough energy to begin to break the bonds in the reactants.

This minimum amount of energy needed for a reaction to occur is called the activation energy.

It if often useful to think of the activation energy as a barrier or "hill" that needs to be overcome for a reaction to begin.

Many chemical reactions require an input energy to start → often is heat... mechanical (stirring) → the reactant will not react by simply mixing them together.

For example: a bbq. The propane and oxygen do not spontaneously ignite as soon as the gas is turned on. A spark or a lighter is needed. The spark provides a few molecules of oxygen and propane with enough energy to overcome the energy barrier and react.

Some chemical reactions do not proceed on their own, or they react slowly.

For example, the decomposition of hydrogen peroxide (H_2O_2) into oxygen gas (O_2) and water (H_2O).

A catalyst can be added to increase the rate of a chemical reaction without being used up itself. (recycled)

An inhibitor is a substance which is used to slow the rate of a chemical reaction.

The SYSTEM and the SURROUNDINGS

Chemists think of energy changes in chemical reactions in terms of energy transfers between the system (chem. reaction) and the surroundings

The system is the materials involved in the chemical reaction and *everything else* in the universe is the surroundings.

IMPORTANT

The Law of Conservation of Energy states that the total energy of the universe is constant → energy cannot be created or destroyed

In terms of a chemical reaction, it means that energy that leaves the system must **enter** the surroundings, and energy that enters the system must **come from** the surroundings.

GCSE Endo

Video: https://www.youtube.com/watch?v=ygyaMUuEyJM **(start @ 2:15)**

While watching the video, follow along and fill in the blanks below:

Energy Transfers in Reactions:

- Chemical reactions become hotter or colder as they proceed
- They give out or absorb heat because of the making and breaking of chemical bonds
- **Making** chemical bonds **releases heat energy** – exothermic
- *Breaking* chemical bonds *requires energy* - endothermic
- Heat input is often needed to start the reaction

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1. Exothermic Reactions

EXAMPLE 1: What happens when the magnesium metal is placed in hydrochloric acid?

$Mg + HCl \rightarrow MgCl_2 + H_2 + HEAT$

↑temperature = EXOthermic

An ***energy diagram*** shows that in an exothermic reaction the products have **LESS ENERGY** than the reactants, so the energy left over heats up the surrounding (explains ↑temp)

Many exothermic reactions require some heat energy to get them started, for example, rocket fuel.

The amount of energy it takes for a reaction to get going is called the activation energy

Summary of Exothermic Reactions:

- More energy is released by the reactants than is needed by the products
- The excess energy is given off as Heat
- Heat input is often needed to provide activation energy to start the reaction
- Heat from the reaction then keeps the reaction going

EXPERIMENT 2: What happens to the atoms when natural gas (methane CH_4) burns in air? *(combustion)*

$CH_4 + O_2 \rightarrow H_2O + CO_2 + heat$

- Heat provides energy to break the bonds in methane and air (O_2)
- Now the atoms can rearrange and form NEW bonds, the reaction products, H_2O and CO_2
- Water and carbon dioxide don't need as much energy as the reactants that formed them, so making bonds releases the excess energy.
- The spare energy goes out as heat, overall the reaction is exothermic

2. Endothermic Reactions

- An endothermic reaction is the opposite of an exothermic reaction
- It absorbs heat

EXPERIMENT 3: What happens to the dry ammonium nitrate crystals and water when an instant ice pack is broken open?

$NH_4NO_3 + H_2O \rightarrow$?

↓temp = endothermic reaction

An energy level diagram shows how the reactants have **LESS energy** than the products.

That means the reactants have a huge energy hill to climb for the reaction to go ahead. ↑ activation energy.

They must steal the energy they need from the surroundings causing the temperature to decrease.

Summary of Endothermic Reactions:

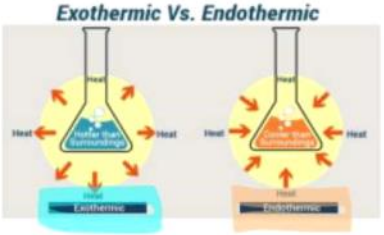
- more energy is needed by the products than is released by the reactants
- The energy shortage is taken in as heat from the surroundings
- This creates a cooling effect

part b) endothermic + exothermic reactions

In any chemical reaction:

1. reactants change into products
2. a change in energy.

Exothermic Vs. Endothermic



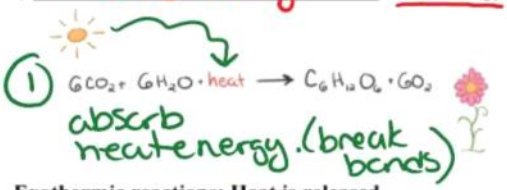
There are two kinds of energy changes in chemical reactions:

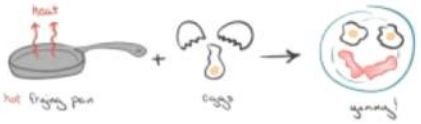
- In an *endothermic reaction*, energy is absorbed by the system from the surroundings. (feel cold, ↓temp.)
- In an *exothermic reaction*, energy is released from the system to the surroundings. (feel hot, ↑temp.)

Endothermic reactions: Heat is absorbed.

1) Photosynthesis: Plants absorb heat energy from sunlight to convert carbon dioxide and water into glucose and oxygen.

2) cooking: Heat energy is absorbed from the pan to cook the egg.





Exothermic reactions: Heat is released.

1) combustion: The burning of carbon-containing compounds ("organic molecule") uses oxygen, from air, and produces carbon dioxide, water, and lots of heat. *For example,*

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O + heat$ (energy is a product)

Chemists experiment on chemical systems containing reactants and products which exchange energy with the surroundings - the container and the rest of the universe.

The ***First Law of Thermodynamics*** states that:

energy cannot be created or destroyed.

This simple statement means that any energy lost by a system must simultaneously be gained by the surroundings (or vice versa).

Why is heat released or absorbed in a chemical reaction?

In any chemical reaction, chemical bonds are either broken or formed. (in many cases.. it's both)

Rule of thumb is:

"When chemical bonds are formed, heat is released, and when chemical bonds are broken, heat is absorbed."

Molecules want to stay together, so **formation of chemical bonds** between molecules requires LESS energy as compared to breaking bonds between molecules, which requires MORE energy and results in heat being absorbed from the surroundings.

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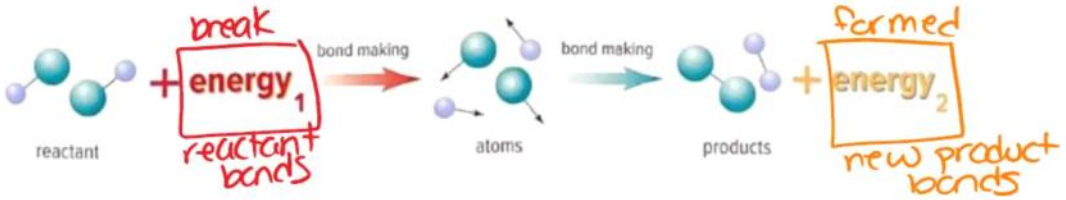
REMEMBER: Energy must be absorbed to break bonds and energy is released when bonds form.

1. Energy is Required to break the bonds between the atoms in the reactants.
   , and immediately afterward
2. Energy is released as the new bonds form between the atoms in the products.

Summarizing:

Bond breaking is always endothermic.
Bond forming is always exothermic.
} *The reaction is either endothermic or exothermic depending on which of these is greater.*

By comparing the total energy required when bonds in the reactants are broken, with the total energy released when bonds in the products are formed, we can determine ***if there is an overall release of energy or absorption of energy.***



Exothermic Reaction: Total energy ***absorbed*** in bond breaking < Total energy ***released*** during bond forming.

energy1 < energy2

Endothermic Reaction: Total energy *absorbed* in bond breaking > Total energy ***released*** during bond forming.

energy1 > energy2

Measuring Energy Changes

Energy changes in a reaction can be monitored by measuring change in temperature.

DEMO 1: $Mg + HCl \longrightarrow H_{2(g)} + MgCl_{2(aq)}$

Did the temperature increase or decrease? yes, the reaction is exothermic (energy is released as heat)

DEMO 2: $Ba(OH)_{2(s)} + 2NH_4NO_{3(s)} \rightarrow Ba(NO_3)_{2(aq)} + 2NH_{3(aq)} + 10H_2O_{(l)}$

Did the temperature increase or decrease? dec., the reaction is endothermic

DEMO 3: $H_2O_2 \xrightarrow{(KI\ catalyst)} H_{2(g)} + O_{2(g)}$

PRACTICE

Did tem. inc. or dec.? inc., the reaction is exothermic

1. **What is an endothermic reaction?**
   breaking bonds ; absorbs energy.
2. **Describe how the energies of reactants and products compare to each other in an exothermic reaction:**
   Exo: energy released reactants < products
3. **If there is a decrease in energy of the system, what happens to the energy of the surroundings?**
   - more energy at start (reactants)
   - energy is absorbed => surroundings feel cold.

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Homework

Assignment #1: Endothermic & Exothermic Reactions
Worksheets pages 6-7

Endothermic and Exothermic Reactions

Below is a set of 20 questions and their answers. However, some of the words have been missed out - see how many of them you can find! You can use the words in the box more than once.

exothermic	temperature	alkali	acid	removed
combustion	reversible	collide	product	respiration
less	products	destroyed	increase	created
energy	reactants	bond	photosynthesis	energy
heat	endothermic	oxidation	bonding	

During a chemical reaction what is always transferred? - energy

Described what is meant by the "conservation of energy" - In a chemical reaction energy cannot be created or destroyed.

How is energy transferred in chemical reactions? - Through the breaking of chemical bonds in the reactants and creating new bonds in the products

What name is given to reactions that transfer energy to the surroundings? - exothermic How do you know that an exothermic reaction has taken place? - Through an increase in temperature from the reactants to the products.

What is the name given to chemical reactions that transfer energy from the surroundings to the reactants? - endothermic

Name 2 examples of an exothermic reaction. - oxidation, combustion respiration or neutralisation

Name 2 examples of an endothermic reaction - ① photosynthesis, (sodium hydrogen-carbonate and citric acid) ② thermal decomposition

What investigation would you do to find out if a reaction is endothermic ro exothermic? - Record initial temperature of reactants and the final temperature to find a total temp. difference.

When you put ice cream into your mouth your mouth feels slightly cool. Why? - During this reaction heat is being removed from the surroundings.

What is a compound? - Substance mad when two or more elements combine through chmical bonding

What does pH7 mean? - The solution is neutral, neither an acid or an alkali (base)

What is meant by the products of a chemical reaction? - The chemical produced as a result of a chemical reaction.

What is meant by the "reactants" in a chemical reaction? - The chemicals that you start off with, before the reaction takes place.

What is meant by "activation energy R "bond energy" ? - The amount of energy needed to break a particular chemical bond. 6

part a) compare + contrast endothermic and exothermic reactions in the following table (hint: write the opposite term/description)

Endothermic	Exothermic
Heat is on the **LEFT**	Heat is on the **RIGHT**
Heat is a **REACTANT**	Heat is a **PRODUCT**
Heat Races **IN**	Heat Pops **OUT**
Reaction **TAKES** Heat	Reaction **MAKES** Heat
Reaction **USES** Heat	Reaction **PRODUCES** Heat
Reaction **ABSORBS** Heat from surroundings	Reaction **RELEASES** Heat into surroundings
Reaction **SUBTRACTS** Heat from surroundings	Reaction **ADDS** Heat to surroundings
Surroundings get **COLDER**	Surroundings get **HOTTER**
Temp of surroundings goes **DOWN**	Temp of surroundings goes **UP**

part b) consider how energy is absorbed or released during phase changes in the following table:

Physical Changes Phase Changes	**Heat is Required, Absorbed from the Surroundings** Heat is Produced, Released into the Surroundings	[Phase Change] is Endothermic **[Phase Change] is Exothermic**	**The Temperature of the Surroundings Decreases** The Temperature of the Surroundings Increases
Melting *Solid → Liquid*	Heat is Required, Absorbed from the Surroundings	Melting is Endothermic	The Temperature of the Surroundings Decreases
Freezing *Liquid → Solid*	Heat is Produced, Released into the Surroundings	Freezing is Exothermic	The Temperature of the Surroundings Increases
Boiling *Liquid → Gas/Vapor*	Heat is Required, Absorbed from the Surroundings	Boiling is Endothermic	The Temperature of the Surroundings Decreases
Evaporating *Liquid → Gas/Vapor*	Heat is Required, Absorbed from the Surroundings	Evaporating is Endothermic	The Temperature of the Surroundings Decreases
Condensing *Gas/Vapor → Liquid*	Heat is Produced, Released into the Surroundings	Condensing is Exothermic	The Temperature of the Surroundings Increases

Part C) enthalpy Δh

ΔH ← enthalpy

"delta" = change

The amount of energy stored in the bonds of the reactants or products in a system is called the Enthalpy (H) (from the Greek word *enthalpein* meaning "to warm").

Enthalpy (measured energy) units = J (kJ)

Since energy will either be ***lost or gained*** by the system during a reaction, the value of H will always different between the reactants and the products.

In other words, there is a **change in energy.**

- In an **endothermic** reaction, more energy will be stored in the products than in the reactants: (energy is NOT released)
  ΔH (+) energy has entered the system $H_{reactants} < H_{products}$
- In an **exothermic** reaction, less energy will be stored in the products than in the reactants:
  ΔH (−) energy has left the system $H_{reactants} > H_{products}$.

We can never really know the internal energy in a system but we ***can measure the change in this energy.***

This change in energy is represented by ΔH where:

$$\Delta H = H \text{ products} - H \text{ reactants}$$

ΔH value negative --> energy released --> exothermic reaction

ΔH value positive --> energy absorbed --> endothermic reaction

Representing Energy Changes within Chemical Reaction Equations

- Enthalpy has units of Joules (J) ← measure of energy.
- Balanced reaction equations that include the enthalpy change are known as **thermochemical equations.**
- Enthalpy is an extensive property *(the energy lost or gained depends on reactant amounts)*
- There are two ways to write them, the *first shown being the preferred way:*

1. Writing the enthalpy change ***immediately after*** the equation - *using the sign of ΔH* to indicate whether the change is endothermic or exothermic.

This form distinguishes exothermic from endothermic by heat term sign

Exothermic Example: $2\,C_8H_{18} + 25\,O_2 \longrightarrow 16\,CO_2 + 18\,H_2O$; $\Delta H = -10\,992$ kJ

Endothermic Example: $6\,CO_2 + 6\,H_2O \longrightarrow C_6H_{12}O_6 + 6\,O_2$ $\Delta H = +393$ kJ

2. Writing the heat term ***within*** the chemical equation - *using the side* to indicate whether the change is endothermic or exothermic.

This form distinguishes exothermic from endothermic by the side the heat term is written on.

energy as product (energy)

Exothermic Example: $2C_8H_{18} + 25O_2 \longrightarrow 16\,CO_2 + 18\,H_2O +$ 10 992 kJ

Endothermic Example: $6\,CO_2 + 6\,H_2O +$ 393 kJ (energy) $\longrightarrow C_6H_{12}O_6 + 6\,O_2$

energy as a reactant

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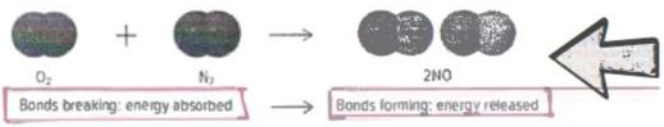
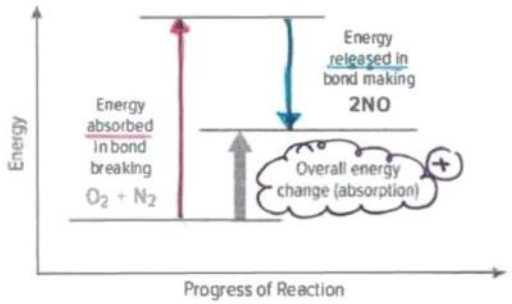
Energy-Level Diagrams

Consider the reaction below: for every molecule of nitrogen that reacts with a molecule of oxygen, 2 molecules of nitrogen monoxide are produced.



- N-N bonds and O-O bonds are **broken.**
- The breaking ___absorbs___ energy.
- ___N-O___ bonds form, and this releases energy.

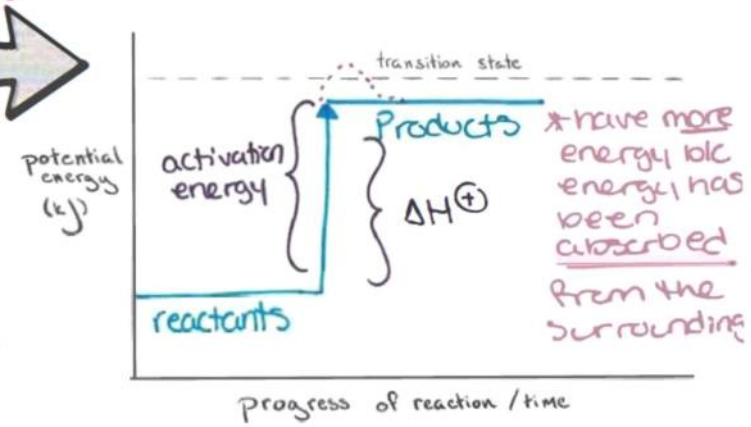
- The total energy absorbed to break each N-N bond and O-O bond is ___MORE___ than the the total energy released when N-O bonds form.
- Therefore, there is an overall absorption of energy, and the reaction is ___ENDOTHERMIC___



The activation energy (E_A) is the ___difference___ in the energy between the ***transition state*** and the reactants.
The enthalpy change (ΔH) is the ___change___ in the energy between the ***reactants and the products***.

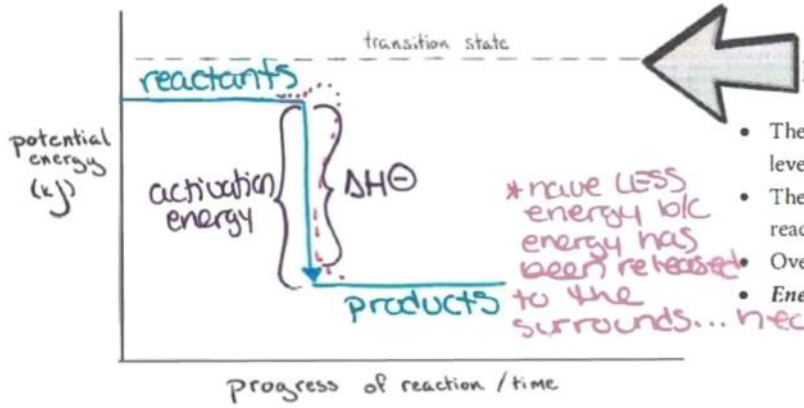
Endothermic Reaction

- The ***reactants are at a lower energy*** level compared to the products
- The ***products are less stable*** than the reactants.
- forcing the reaction in the forward direction towards more unstable species
- overall ΔH for the reaction is ***positive,***
- energy is absorbed from the surroundings.



Exothermic Reaction

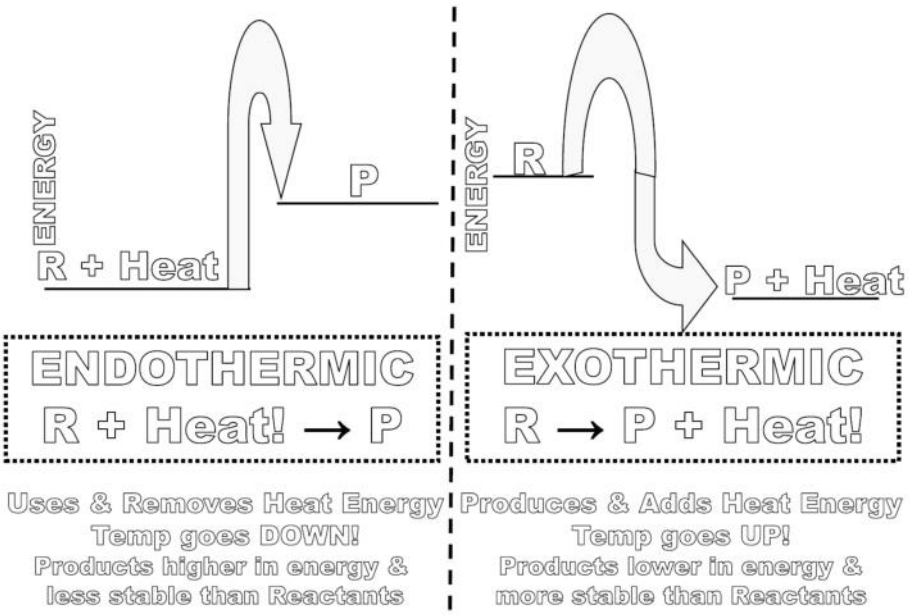
- The ***reactants are at a higher energy*** level compared to the products
- The ***products are more stable*** than the reactants.
- Overall ΔH for the reaction is ***negative***
- ***Energy is released*** in the form of ***heat.***



Homework

Assignment #2 Complete the following worksheets on Energy in Reactions: Endothermic & Exothermic Reactions

Part A: Energy Change Diagram
label the energy change diagrams and describe characteristics of these energy graphs to compare endo vs. exothermic reactions



Part B: Interpreting Energy in Chemical Formulas
complete the table below by interpreting what it means what HEAT is a reactant or a product. The first one has been done for you as an example.

Chemical Changes (= chemical rxns)	**Heat is a Reactant: The Rxn is Endothermic** Heat is a Product : The Rxn is Exothermic	Rxn Takes, Uses & Absorbs Heat **Rxn Makes, Produces & Releases Heat**
$Zn + S \rightarrow ZnS + Heat$	Heat is a Product: Rxn is Exothermic	Rxn Makes, Produces & Releases Heat
$2H_2O_2 \rightarrow 2H_2O + O_2 + Heat$	Heat is a Product: Rxn is Exothermic	Rxn Makes, Produces & Releases Heat
$Ba(OH)_2 + 2NH_4Cl + Heat \rightarrow BaCl_2 + 2NH_4OH$	Heat is a Reactant: Rxn is Endothermic	Rxn Takes, Uses & Absorbs Heat
$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O + Heat$	Heat is a Product: Rxn is Exothermic	Rxn Makes, Produces & Releases Heat
$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O + Heat$	Heat is a Product: Rxn is Exothermic	Rxn Makes, Produces & Releases Heat
$2Fe_2O_3 + 3C + Heat \rightarrow 3CO_2 + 4Fe$	Heat is a Reactant: Rxn is Endothermic	Rxn Takes, Uses & Absorbs Heat
$2Na + Cl_2 \rightarrow 2NaCl + Heat$	Heat is a Product: Rxn is Exothermic	Rxn Makes, Produces & Releases Heat
$CitH_3 + 3NaHCO_3 + Heat \rightarrow CitNa_3 + 3H_2O + 3CO_2$	Heat is a Reactant: Rxn is Endothermic	Rxn Takes, Uses & Absorbs Heat
$(NH_4)_2Cr_2O_7 \rightarrow N_2 + 4H_2O + Cr_2O_3 + Heat$	Heat is a Product: Rxn is Exothermic	Rxn Makes, Produces & Releases Heat
$2Al + Fe_2O_3 \rightarrow Al_2O_3 + 2Fe + Heat$	Heat is a Product: Rxn is Exothermic	Rxn Makes, Produces & Releases Heat

Homework **Assignment #3: Concept Review: Energy in Chemical Reactions**
answer the questions in the space provided below

Check Your Understanding

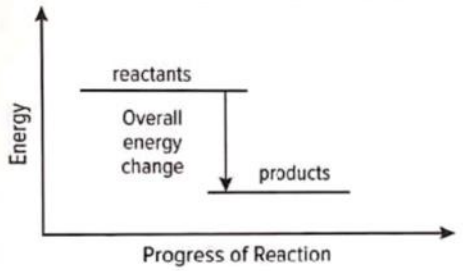
Understanding Key Ideas

1. Describe an example of a physical change or chemical change that is endothermic and a physical or chemical change that is exothermic. PA

2. Compare the overall energy changes that occur in endothermic reactions with those that occur in exothermic reactions. How are the energies of bond formation and bond breaking involved? PA E

3. Draw a sketch of the overall transfer of energy between the system and surroundings for an endothermic reaction. C

4. An energy-level diagram is shown below.



   a) Does the diagram represent an exothermic or endothermic reaction? Explain. PA

   b) Draw a diagram that would represent a greater overall energy change. C

Connecting Ideas

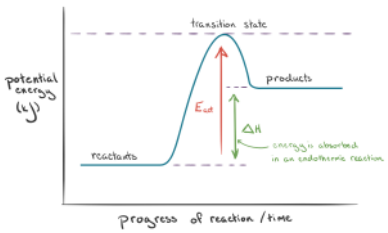
5. Students perform a chemical reaction in a glass test tube. They notice that the test tube feels cooler than it did before the reactants were added. PC PA

   a) Did the students most likely perform an exothermic or endothermic reaction?

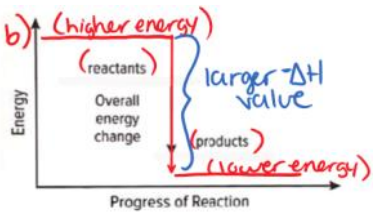
   b) What data could the students collect to confirm the type of reaction?

   c) Identify the system and the surroundings in this investigation.

1. Physical change (endothermic): *melting an ice cube, evaporation*
   Chemical change (endothermic): *rusting, photosynthesis, cooking*
   Physical change (exothermic): *freezing, condensation*
   Chemical change (exothermic)*: any combustion reactions*
2. Bond breaking requires energy, so it is endothermic. Bond formation is an exothermic process. Less energy is required to FORM bonds than is required to break, therefore when bonds form there is excess energy left over, which is released (exothermic rxns release/produce energy)
3. :



4 a) the diagram represents an exothermic reaction. Because the overall energy change has decreased (-ΔH = exothermic reaction) meaning that energy has been released



5.

a) endothermic reaction

b) If the students noticed that the test tube "felt cooler" they could measure and record the temperature of the reaction to confirm if energy has been absorbed or released.

c) The chemical reaction the students are performing is the "system" and anything else (the world around it) is considered the "surroundings"

1 1

Check Your Understanding

6. Is melting an ice cube an endothermic or exothermic process? Explain. OP AI

7. Although many individual reactions are part of photosynthesis and cellular respiration, the following chemical equations can be used to represent the overall processes.

Photosynthesis:

$6H_2O + 6CO_2 + \text{energy} \rightarrow 6O_2 + C_6H_{12}O_6$

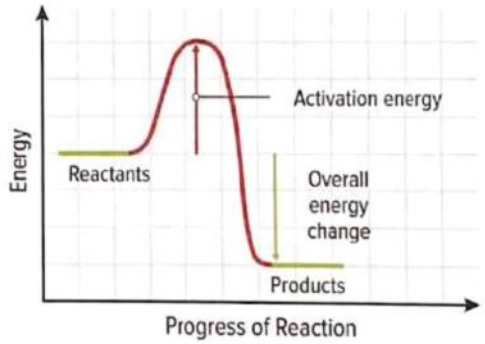
Cellular respiration:

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{energy}$

Is photosynthesis an endothermic process or an exothermic process? What about cellular respiration? Explain your answers. OP PA E

Making New Connections

8. The image below shows another way that energy changes in a chemical reaction can be represented. E AI



a) What is activation energy? Why do you think it is represented as a "hill"?

b) Describe the relative energy levels of the reactants and products.

c) Does this diagram represent an exothermic or endothermic reaction? Explain your answer.

d) Infer which are the most stable particles in the reaction. Which are the least stable? Justify your responses based on the energies of the particles.

6. Melting an ice cube is an endothermic process. This is because to phase change from a solid --> liquid, chemical bonds must be broken. Bond breaking always REQUIRES ENERGY=endothermic.

7. Photosynthesis is an endothermic process because energy is a reactant, meaning that energy is absorbed or required for the reaction to proceed. Cellular respiration is an exothermic reaction. This is because energy is a product, meaning that energy is released to the surroundings.

8. *Making new Connections:*

a) Activation energy is the energy needed to be absorbed by the reactants in order to break the bonds. In other words, it is the energy needed in order for the reaction to proceed. It is represented as a "hill" visually because it is the minimum threshold energy in order to break bonds and then begin forming products. *"the hill you have to climb and get over in order to make products"*

b) In this example the reactants are higher energy, and the products have lower energy. *(not always the case, but this reaction is exothermic, so the products will always have lower energy in an exothermic reaction because excess energy has been released)*

c) This reaction is exothermic because there is a negative ΔH (the overall energy change decreases from reactants to products). This means that excess energy is released.

d) Stable refers to "energetically stable". In chemistry, when molecules or compounds are "lower energy" they are **more** stable. So in this example, the products would be more stable, because they have lower energy. That means the reactants would be the least stable, because they have higher energy than the products. *(this is all based on the scale on the graph)*