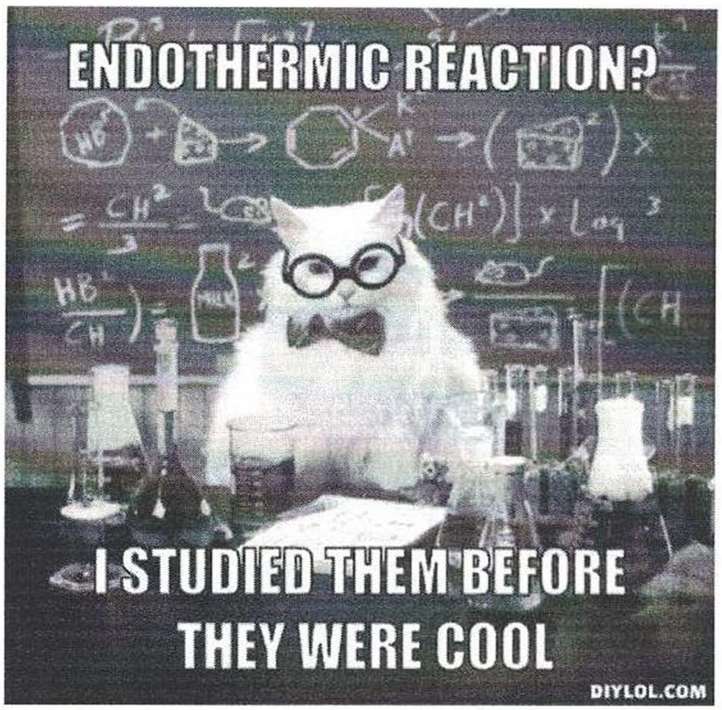
SCIENCE 10

UNIT 2: CHEMISTRY

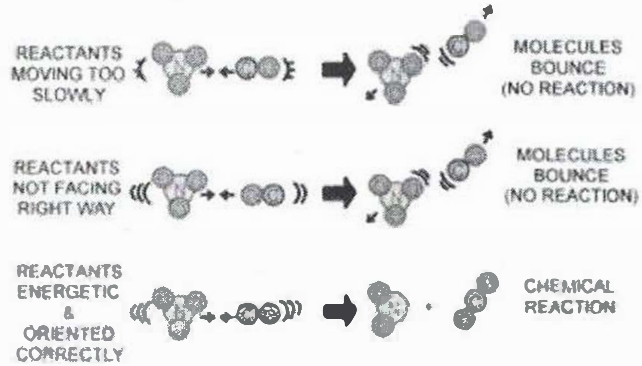


BOOK 5: ENERGY CHANGES IN CHEMICAL REACTIONS

NAME: Key. BLOCK: ________

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 ___initial input of energy___ → 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.

The SYSTEM and the SURROUNDINGS

Chemists think of energy changes in chemical reactions in terms of energy transfers between the ___system___ and the ___surroundings___

The system is the materials involved in the ___chemical rxn___ 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.

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

1. Exothermic Reactions

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

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

• temperature ↑ = exothermic rxn.

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 surroundings. (explains the 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 (→ into the surroundings.) 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

The Experiment **EXPERIMENT 2:** What happens to the atoms when natural gas (methane CH_4) burns in air? *(combustion)* $CH_{4(l)} + O_{2(g)} \rightarrow H_2O_{(l)} + CO_{2(g)} + heat$

- 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, $H_2O_{(l)}$ and $CO_{2(g)}$
- 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

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

$NH_4NO_{3(s)} + H_2O_{(l)} \rightarrow$

• temp ↓ = endothermic

*complex acid-base rxn. you don't need to be able to predict products.

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.

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

Summary of Endothermic Reactions:

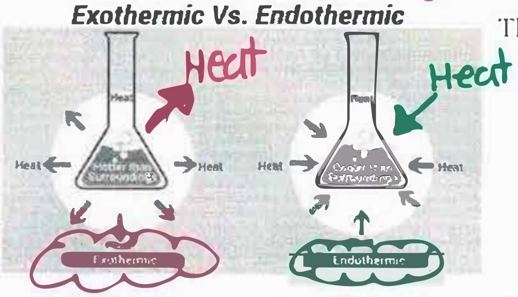
- MORE energy is needed by the products than is released by the reactants
- The energy shortage is taken in as heat from the surroundings
- This creates a cooling effect

Exothermic and Endothermic Reactions

In any chemical reaction:

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

Exothermic Vs. Endothermic



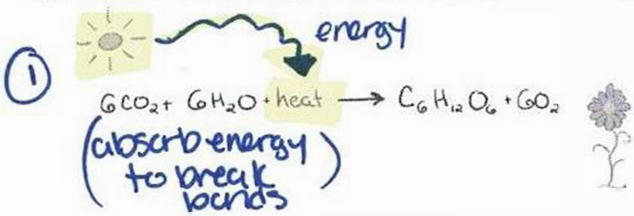
There are two kinds of energy changes in chemical reactions:

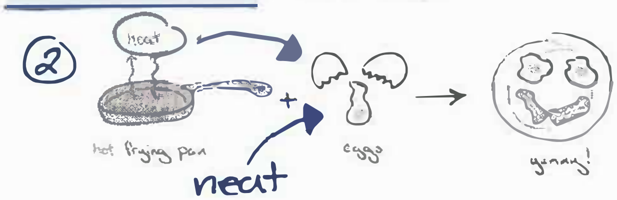
- In an ***endothermic reaction***, energy is absorbed (cold feeling) by the system from the surroundings.
- In an ***exothermic reaction***, energy is released (feels hot) from the system to the surroundings.

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 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: 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?

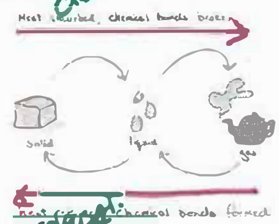
In any chemical reaction, chemical bonds are either broken or formed.

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.

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



1. Energy is __Required__ to break the bonds between the atoms in the reactants.

... *and immediately afterward ...*

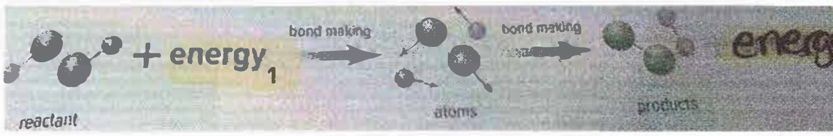
2. Energy is __Released__ as the new bonds form between the atoms in the products.

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. • energy required to break reactants < energy to form prod

DEMO 1: Mg + HCl → $MgCl_2$ + $H_{2(g)}$ + heat

Did the temperature increase or decrease? ↑, the reaction is EXOTHERMIC

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

Did the temperature increase or decrease? ↓, the reaction is ENDOTHERMIC

energy absorbed to break reactants > energy released to form products.

Enthalpy ΔH

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").

Since energy will either be ***lost or gained*** by the system during a reaction, the value of H will __always be 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: __+ΔH__
  energy has entered 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 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***.

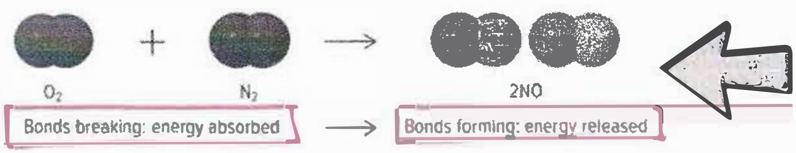
This **change in energy** is represented by **ΔH** where:

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

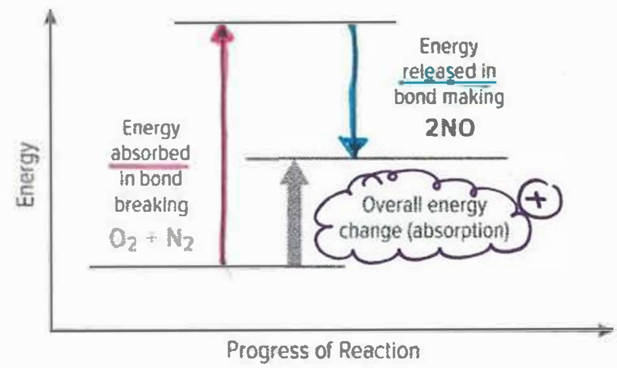
ΔH value negative --> energy released --> exothermic reaction
ΔH value positive --> energy absorbed --> endothermic reaction

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.

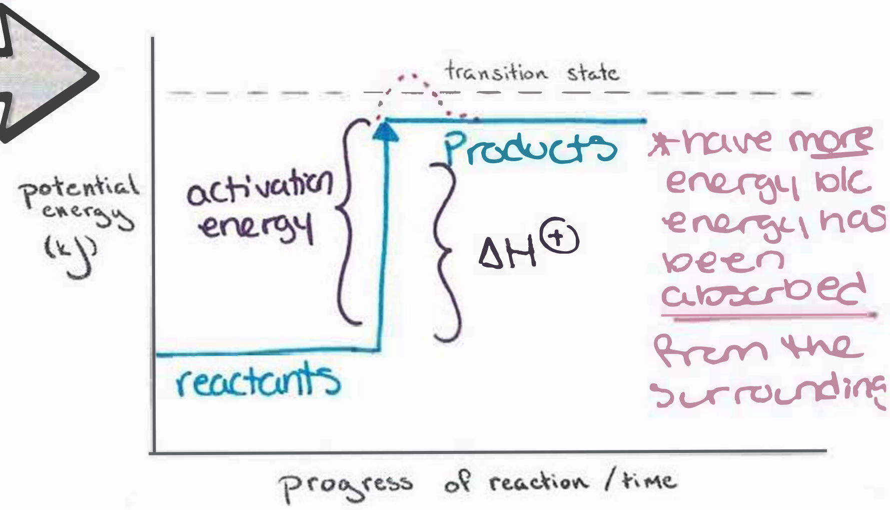


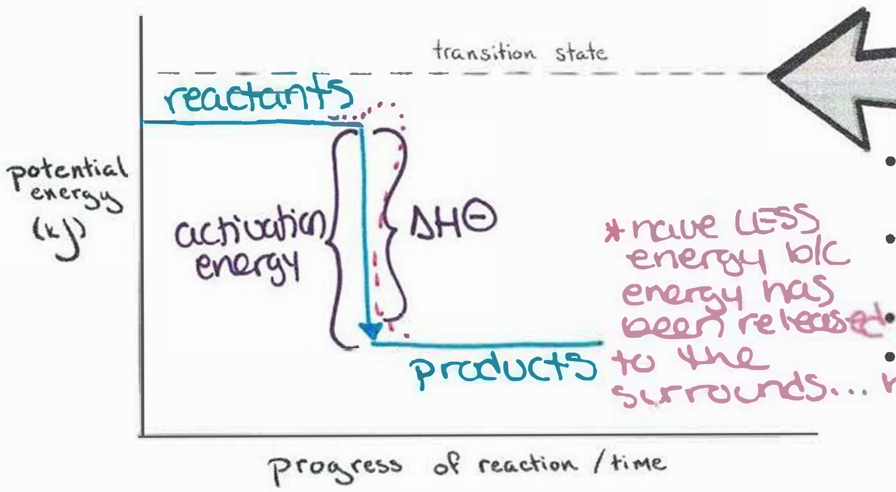
- The total energy absorbed to break each N-N bond and O-O bond is ___MORE___ than the the total energy released when N-O bonds form.
- Therefore, there is an overall absorption of energy, and the reaction is ___ENDOTHERMIC___

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***.

heat released.

Representing Energy Changes within Chemical Reaction Equations

- Enthalpy has units of ___Joules___ (J)
- 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: $2\,C_8H_{18} + 25\,O_2 \longrightarrow 16\,CO_2 + 18\,H_2O$; ΔH = ___- 10 992 kJ___

Endothermic Example: $6\,CO_2 + 6\,H_2O \longrightarrow C_6H_{12}O_6 + 6\,O_2$; ΔH = ___+ 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.

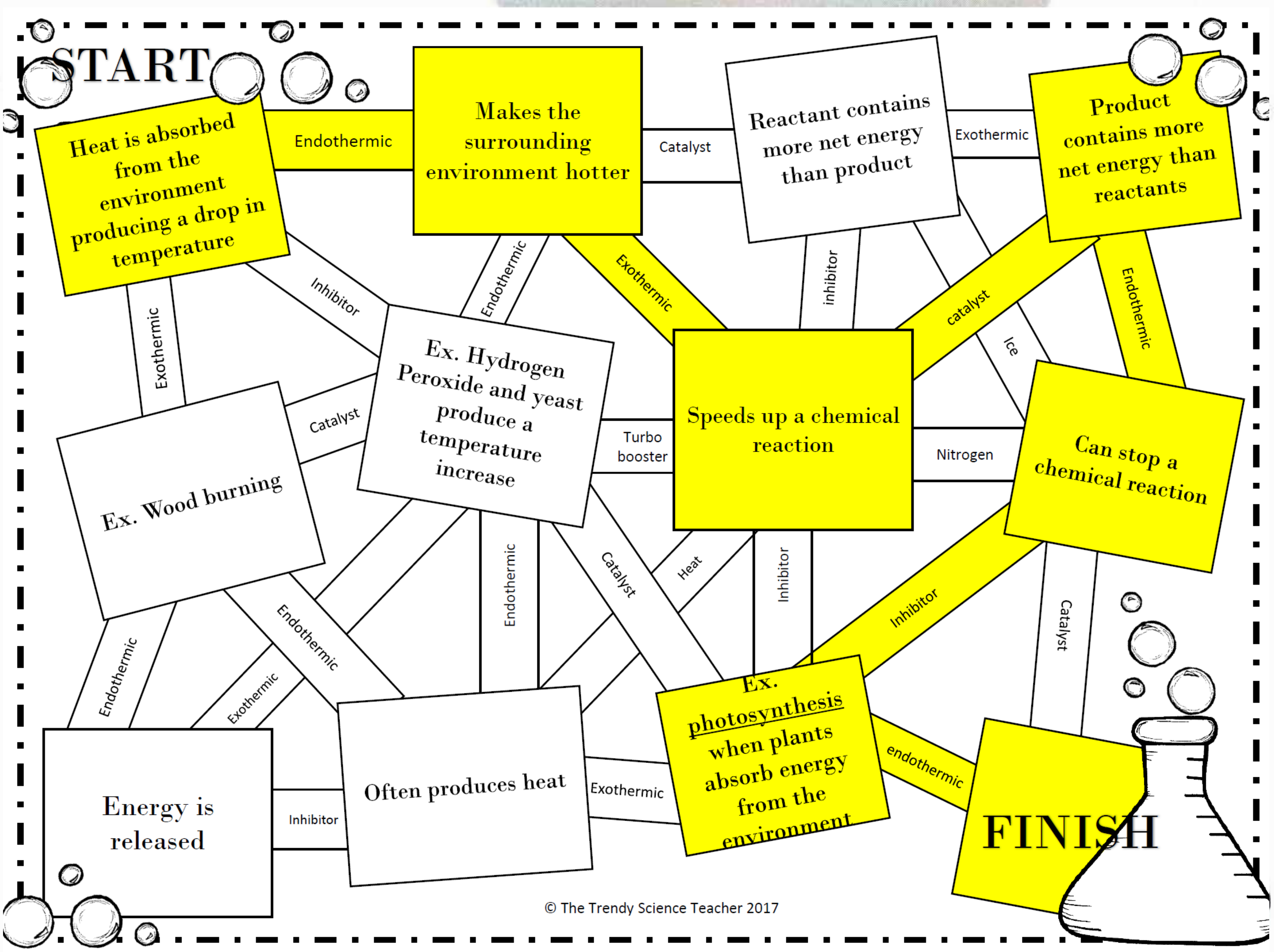
energy/heat is a product

Exothermic Example: $2C_8H_{18} + 25O_2 \longrightarrow 16\,CO_2 + 18\,H_2O +$ ___10992 kJ___

Endothermic Example: $6\,CO_2 + 6\,H_2O +$ ___393 kJ___ $\longrightarrow C_6H_{12}O_6 + 6\,O_2$

energy/Heat is a reactant

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



Part A: 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 - **photosynthesis**, sodium hydrogen-carbonate and citric acid or thermal decomposition

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

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

What is a compound? - Substance made when two or more elements combine through chemical **bonding**.

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

What is meant by the term "oxidation"? - A chemical reaction where oxygen is added to a substance, or when electrons are lost from a substance.

What is meant by a "reversible" reaction? - A reaction that can revert back to the original reactants.

What is meant by the product 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 "bond energy"? - The amount of energy needed to break a particular chemical bond.

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.

A Endothermic vs. Exothermic Changes Last ______ first ______

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