Change is **COOL!**

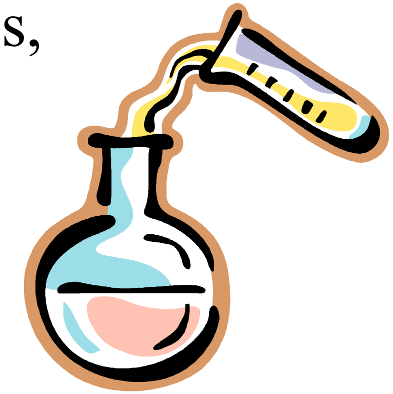
-What is a chemical reaction?

A Chemical Reaction is a process in which one or more substances change into new substance(s) having different physical and chemical properties.

-What is the evidence for a chemical reaction?

Energy Changes: heat, light, sound or electrical energy changes.

New Substances: gas, solid, liquid, water, color changes, odor changes.



- **Word Equations**
  - “Sodium metal burns in chlorine gas to form solid sodium chloride.”
- **Formula Equations**
  - $Na + Cl_2 \rightarrow NaCl$
    - *(Why is it Cl_2, not simply Cl?)*

- **Reactants: starting substances (left).**
- **Products: ending substances (right).**
- **Plus sign (+)** means “reacts with.”
- ***Arrow sign (→)*** means “yields.”
- **Coefficients:** how many units of each substance are present (whole numbers written before reactants & products).
- **Subscripts:** how many of each atom type are in a substance (subscripts in formulas).
  - **REMINDER**: Don’t change the subscripts of a correctly written formula!

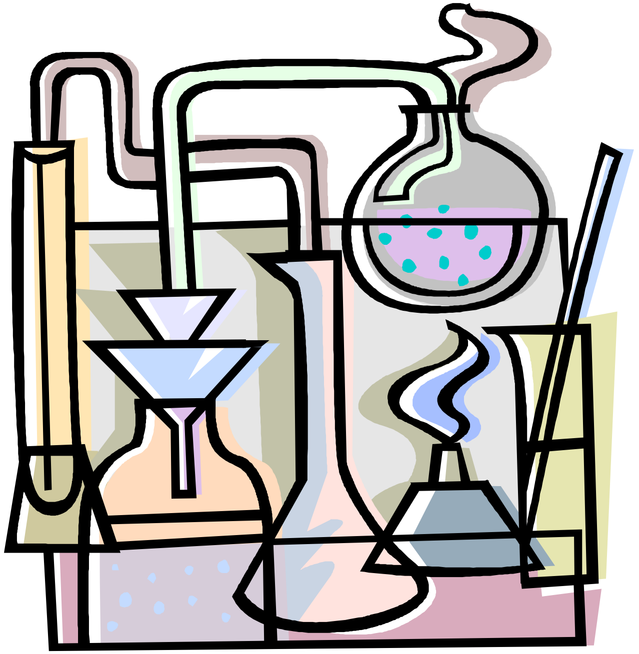
- Definitions:

  (*s*) = solid

  (*l*) = liquid

  (*g*) = gas

  (*aq*) = aqueous (water) solution



(*s*) ¯ means “a solid (precipitate) is formed.”

(*g*) ↑ means “a gas is produced.”

(*aq*) means “dissolved in water solution.”

$\xrightarrow{\textbf{heat}}$ means “reacts with heat.” (or Δ)

$\xrightarrow{\textbf{catalyst}}$ means “reacts with a catalyst present.”

A **catalyst** is a substance that speeds up a reaction, but does not get consumed in the reaction.)

Precipitate is a solid that suddenly appears when that phase was not initially present, *i.e.* two liquids are mixed and you get a solid.

- **Purpose**
- The purpose is to determine the ratio of copper produced to iron consumed in a reaction.
- **Procedure**
- **Day 1**
- 1.Label, then mass a 250 mL beaker.
- 2.Put between 6.0 and 8.5 g of copper(II) chloride in the beaker.
- 3.Add about 50 mL distilled water to the beaker. Stir to dissolve the solid.
- 4.Mass 2 or 3 nails together to ± 0.01g.
- 5.Place the nails in the copper chloride solution. Observe the reaction; record your observations. Place the labeled beaker in the hood.

Data:

Mass 250 mL beaker	
Mass 250 mL beaker + copper(II) chloride	
Mass nails before reaction	

Day 2

- 6.Remove the nails. Rinse or scrape the precipitate (copper metal) from the nails into your labeled 250 mL beaker. Place the nails in a labeled small beaker. Note the appearance of the nails. Place this beaker on tray labeled nails.
- 7.Decant solution from the 250 mL beaker. Rinse the precipitate with about 25 mL of distilled water. Try to lose as little of the solid copper as you can when you decant. After a 2nd rinse with distilled water, rinse the copper with 25 mL of 1 M HCl. Rinse one last time with distilled water. Then place the labeled beaker on the tray labeled copper.

Day 3

- 8. Mass the dry nails, then discard the nails.
- 9.Mass the beaker + dry copper. Discard the copper in the designated waste container. Wash your beaker and let dry.

Mass nails after reaction	
Mass 250 mL beaker + dry copper	

Calculations:

- 1. Determine the mass of copper produced and the mass of iron used during the reaction.
- 2.Calculate the moles of copper and moles of iron involved in the reaction.
- 3.Determine the ratio $\frac{\text{moles of copper.}}{\text{moles of iron}}$

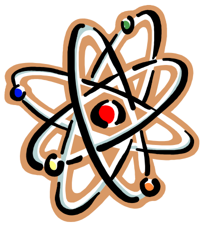
- Express this ratio as an integer. For example, a ratio of 1.33 can be expressed as 4/3; 0.67 can be expressed as 2/3 , etc.

Conclusion:

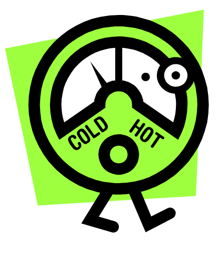
- 1.Why did the reaction stop? Which reactant was used up? How do you know?
- 2.Describe what was happening to the atoms of iron and copper during the reaction. What is this type of reaction called?
- 3.What would happen to the ratio of copper to iron if you had placed more nails in the beaker? If you let the reaction go for less time?
- 4.What is the accepted ratio of copper atoms to iron atoms in this reaction? Account for differences between your experimental value and the accepted value.
  Write the balanced equation for the reaction.

- Be prepared to:
- Present your results from the lab and discuss how changes could be represented symbolically.
- To help visualize the process, represent the changes using different color circles
- Verbalize what is happening to the atoms of each substance during the reaction.
- Translate your physical representation and description of the reaction into a symbolic representation

- http://www.chem.iastate.edu/group/Greenbowe/sections/projectfolder/flashfiles/redox/home.swf

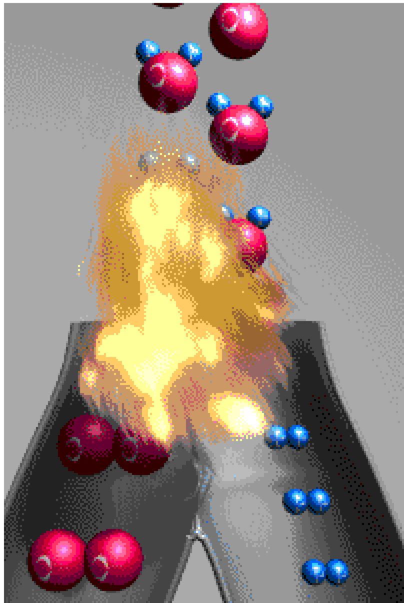


- **Why do chemical reactions occur?**
- The arrangement of electrons in atoms determines the direction and outcome of chemical reactions.
- Energy changes are involved in chemical reactions, and reactions occur because existing bonds are broken, atoms are rearranged, and new bonds are formed.
  - Energy may be released, exothermic (burning methane).
  - Energy may be absorbed, endothermic (ice packs).
- Overall, the energy of the products is lower than that of the reactants when reactions occur, but energy is sometimes needed to start a reaction.



Example

______O_2+ ______$H_2 \rightarrow$ ______ H_2O



Procedure:

1. Use your kit to construct the **reactant** molecules for each chemical change. Then rearrange the atoms to form the **product** molecules. Add more reactant molecules as needed to form complete product molecules with **no leftovers.**
2. Draw **particle diagrams** for each reactant molecule used and each product molecule produced under the reaction.
3. Determine the number of each reactant molecule you needed in order to make the product(s) with no leftovers (a complete reaction) and record each number as a **coefficient** in front of its reactant formula.
4. Determine how many product molecules you would get from the complete reaction. Write that number as a **coefficient** in front of each product formula.

- the rearrangement process of a chemical reaction requires that all atoms from the reactant molecules MUST become part of one of the products. The conservation of mass we observed at the beginning of the course is evident during chemical reactions;
- **coefficients** describe how many whole particles of each substance are either consumed or formed, while **subscripts** describe the count of atoms in a substance;
- reactions proceed by first breaking bonds between atoms in the reactants, and then forming new bonds between these atoms to make the products.

$H_2 + O_2 \rightarrow H_20$

We are going to use a technique called atomic inventory to help balance….

$H_2 + O_2 \rightarrow H_20$

2 H				2		
O	4	2		2	4	
		2		1	2	Is it balanced?

Now it is balanced!

1 SKILLS Toolkit

Balancing Chemical Equations

1. Identify reactants and products.

- If no equation is provided, identify the reactants and products and write an unbalanced equation for the reaction. (You may find it helpful to write a word equation first.)
- If not all chemicals are described in the problem, try to predict the missing chemicals based on the type of reaction.

2. Count atoms.

- Count the number of atoms of each element in the reactants and in the products, and record the results in a table.
- Identify elements that appear in only one reactant and in only one product, and balance the atoms of those elements first. Delay the balancing of atoms (often hydrogen and oxygen) that appear in more than one reactant or product.
- If a polyatomic ion appears on both sides of the equation, treat it as a single unit in your counts.

3 Insert coefficients.

Add a coefficient of 2 in front of Fe to balance the iron atoms.

$$Fe_2O_3 + H_2 \longrightarrow 2Fe + H_2O$$

Add a coefficient of 3 in front of H_2O to balance the oxygen atoms.

$$Fe_2O_3 + H_2 \longrightarrow 2Fe + 3H_2O$$

Now there are two hydrogen atoms in the reactants and six in the products. Add a coefficient of 3 in front of H_2.

$$Fe_2O_3 + 3H_2 \longrightarrow 2Fe + 3H_2O$$

4 Verify your results.

There are two iron atoms, three oxygen atoms, and six hydrogen atoms on both sides of the equation, so it is balanced.

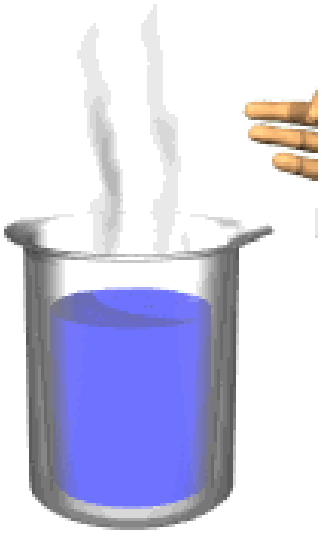
PRACTICE

Write a balanced equation for each of the following.

1. $P_4 + O_2 \longrightarrow P_2O_5$
2. $C_3H_8 + O_2 \longrightarrow CO_2 + H_2O$
3. $Ca_2Si + Cl_2 \longrightarrow CaCl_2 + SiCl_4$

- In the same way that atoms combine in definite ways to form compounds, chemical changes also occur in **patterns** that help us to predict the outcome of some of the common changes.
- Remember – breaking and forming bonds requires transfer of energy in or out of the system (Ech)
- In addition to looking at the ways atoms rearrange, you also needs to watch for evidence of energy changes during the reactions

- Combination (synthesis)
- Decomposition
- Single replacement
- Double replacement
- Combustion



Prepare whiteboard presentation:

- Observed evidence of reaction
- Balanced equation for the reaction AND word equation
- Energy component (if observed) and which side of the equation it should be on
- Did chem. energy increase or decrease during the change?
- Is it an endothermic or exothermic reaction?
- Particle diagram of mixture before and after reaction is complete
- Were your reactants in the exact reaction ratio when you mixed them?
- How would your picture be different if the ratio in your container were different from the balanced equation? What would you find in your container after the reaction stopped?

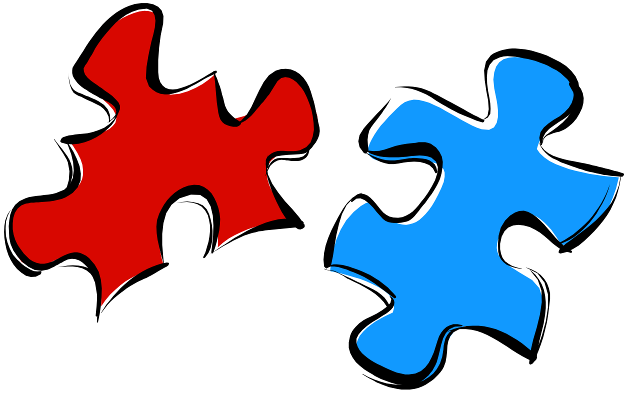
- **Synthesis (combination)** - two or more reactants combine to form one product.

- $A + B \rightarrow AB$
- $A + 2 B \rightarrow AB_2$

- $N_2 + 3 H_2 \rightarrow 2 NH_3$

- **Decomposition** - one reactant breaks into two or more products.

- AB → A + B
- 2 A_2B → 4 A + B_2

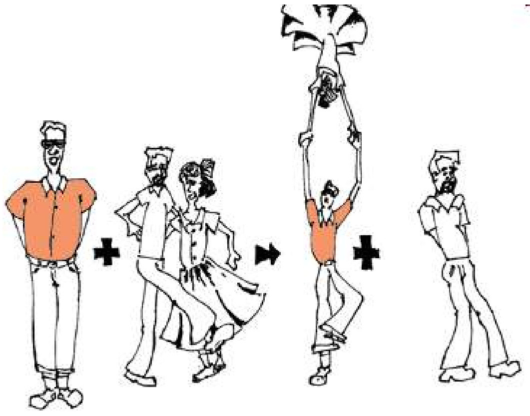


- **2 $KClO_3$ → 2 KCl + 3 O_2**

- **<u>Single Replacement/Displacement</u>** - an element reacts with a compound, and part of the compound is replaced by the
- element. (Metals replace metals, and nonmetals replace nonmetals.)

A + BC → AC + B

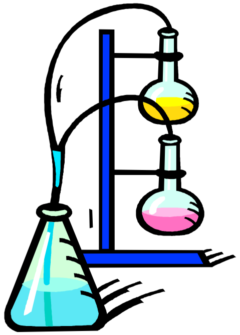
Cu + H_2SO_4 → $CuSO_4$ + $H_2(g)$↑



- **Double Replacement/Displacement** - one compound reacts with another compound, and they change partners. (Each cation goes with the opposite anion.)

- AB + CD → AD + CB
- **$CaCl_2$ + $(NH_4)_2O$ → CaO + 2 NH_4Cl**

- **Combustion** - a substance reacts with oxygen, and everything ends up attached to oxygen.
- $CH_x + O_2 \rightarrow CO_2 + H_2O$
- $CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$



- **Redox (Oxidation/Reduction)** - a reaction involving substances that gain or lose electrons; both processes occur together, and the reactions may be simple or complex.

- $K_2Cr_2O_7 + 14\ HI \rightarrow 2CrI_3 + 2KI + 3\ I_2 + 7H_2O$

- http://www.marymount.k12.ny.us/marynet/stwbwk05/05hchemistry.html

- $H_2 + O_2 \rightarrow H_2O$
- $BaCl_2 + Br_2 \rightarrow BaBr_2 + Cl_2$
- $BaCl_2 \rightarrow Ba + Cl_2$

- Substances store varying amounts of chemical potential energy (Ech) due to the arrangement of atoms.
- It is not possible to measure this amount of energy directly. However, rearrangement of atoms during reaction produces changes in Eth
- the resulting energy transfers (as Q) between system and surroundings can be measured
- can deduce differences in the Ech of reactants and products.
- Energy bar graphs are a useful tool for accounting for energy (stored and transferred) during chemical change.

- Use energy bar diagrams to represent energy accounts at **various stages** of reaction
- Provide mechanism for change
- Connect thermal and chemical potential energy
- Focus on what is happening during the course of the reaction

- How do you know on which side to write the energy term?
  - If you had to **supply energy** to the reactants, the products **store more energy**

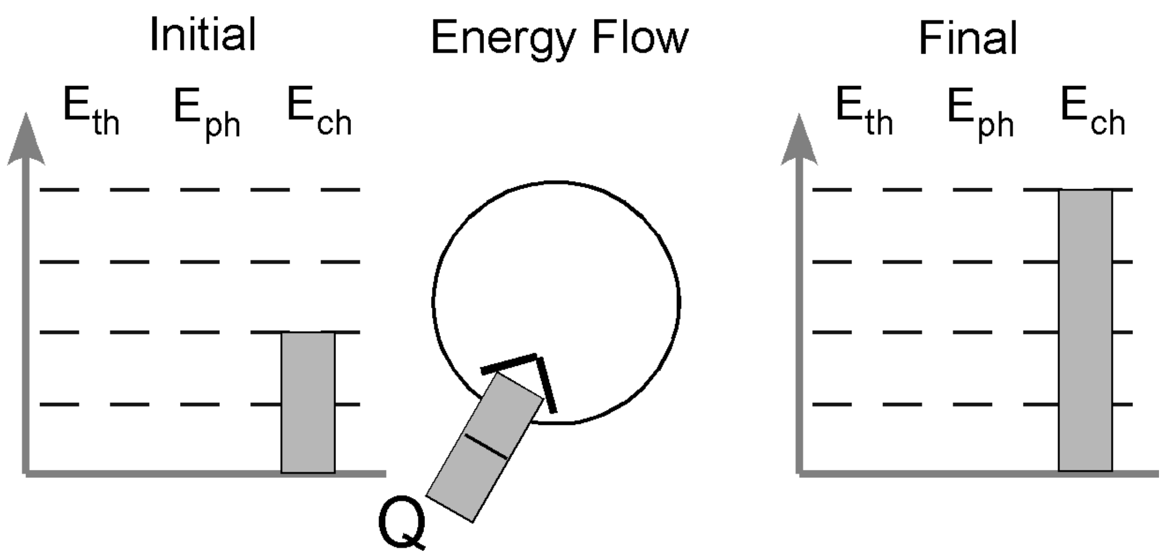
  energy + $CaCO_3 \rightarrow CaO + CO_2$ (g)

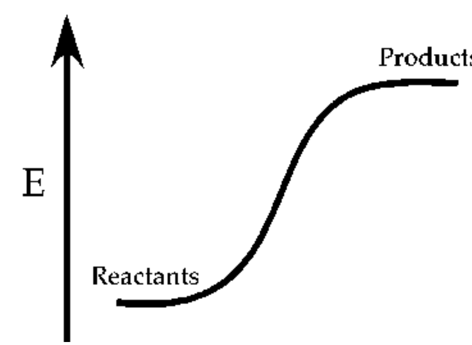
  - If uncertain, use analogy from algebra

  If 3 + y = x, which is greater, y or x?

  - Consistent with generalization that separated particles have more energy

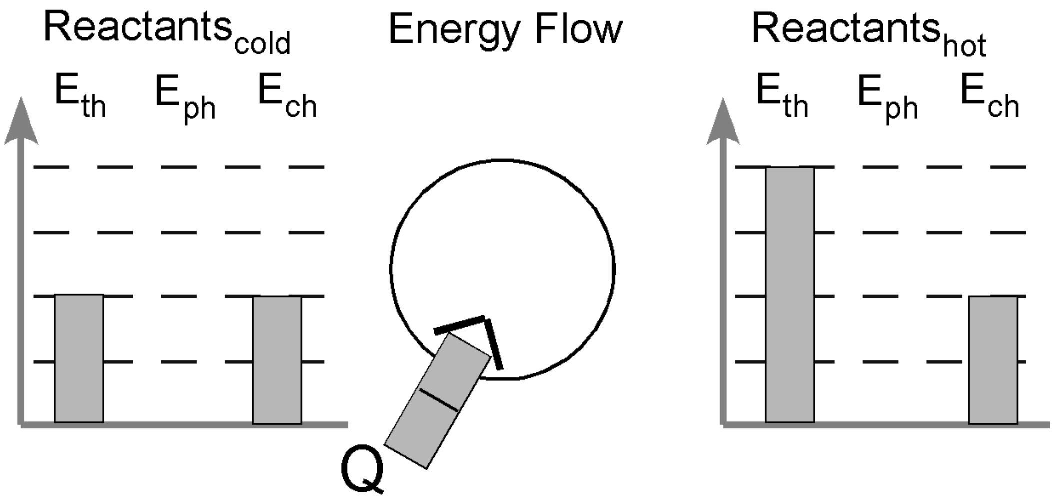
- Show energy transfers between surroundings and system



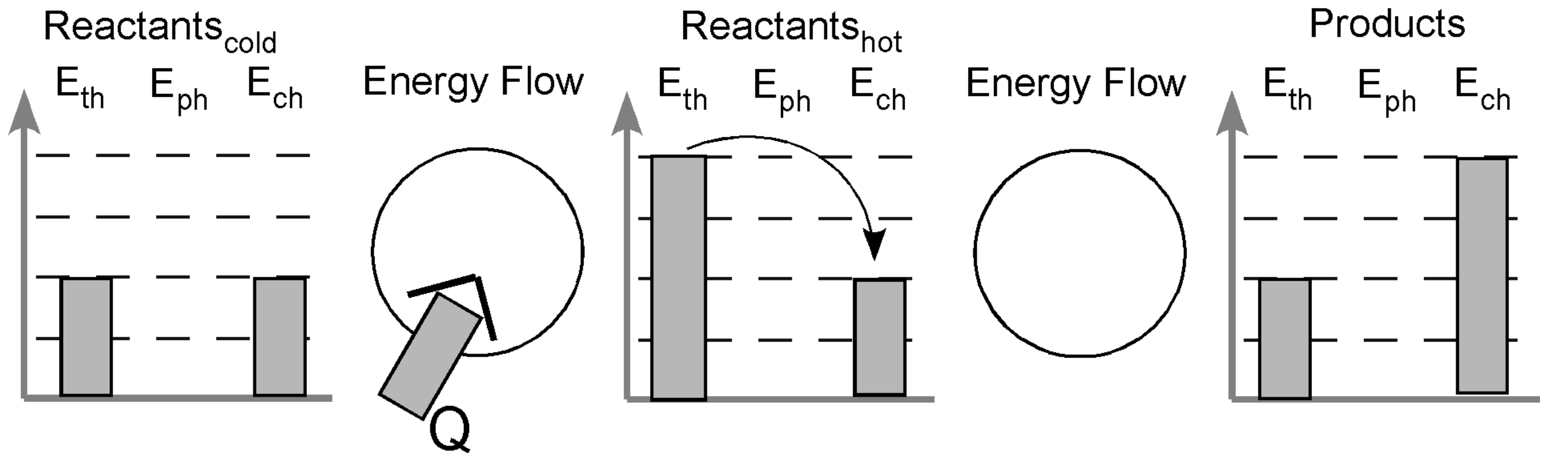


- How does heating the reactants result in an increase in E_{ch}?
- Energy to rearrange atoms in molecules must come from *collisions* of molecules
- Low energy collisions are unlikely to produce molecular rearrangement

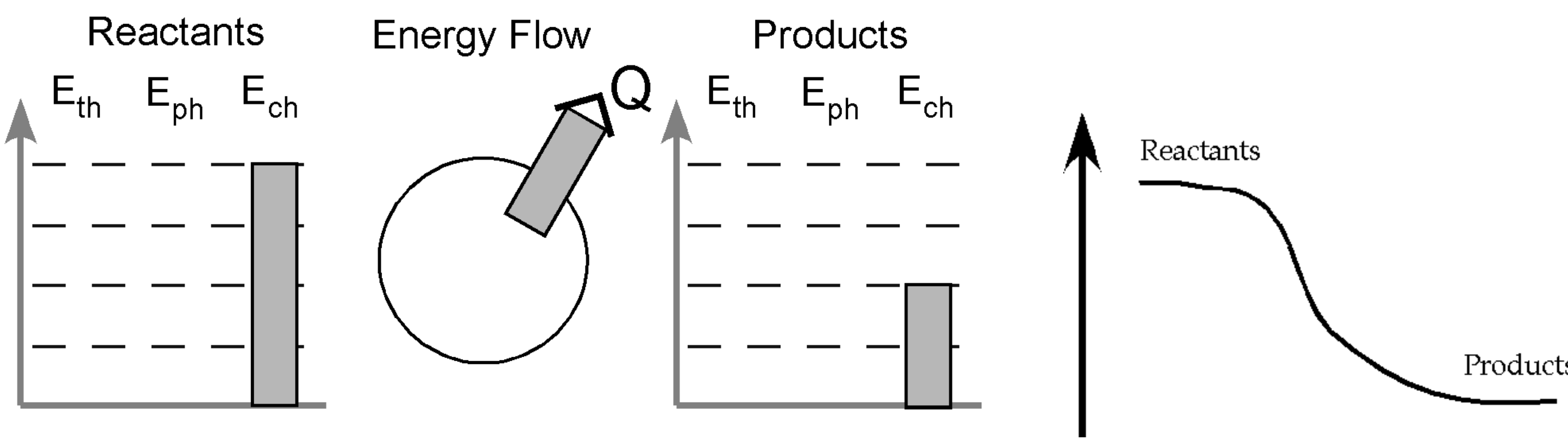
- Hotter, faster molecules (surroundings) transfer energy to colder, slower molecules (system)
- Now reactant molecules are sufficiently energetic to produce reaction



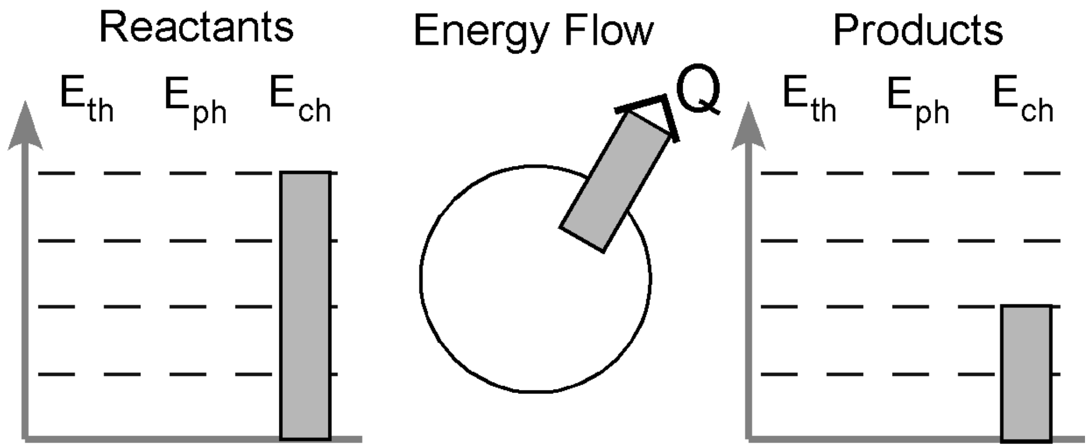
1. Heating system increases E_{th} of reactant molecules
2. Energy is transferred from E_{th} to E_{ch} now stored in new arrangement of atoms
3. Resulting system is cooler - requires continued heating to bring E_{th} back up to level required to sustain reaction



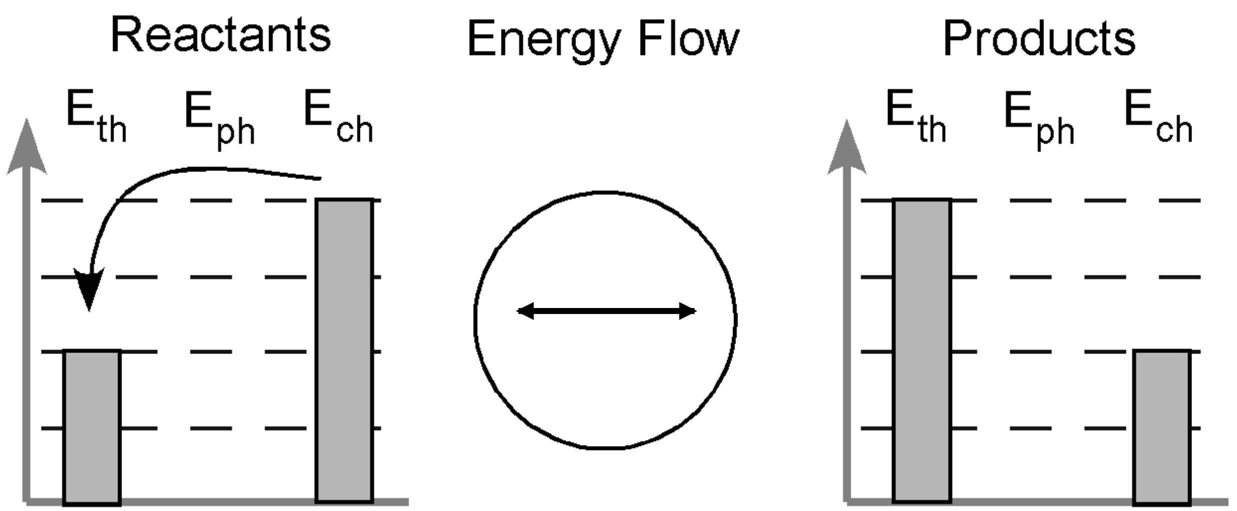
- How do you know on which side to write the energy term?
  - If energy flows from system to surroundings, then the products must store less E_{ch} than the reactants
  - $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ + energy



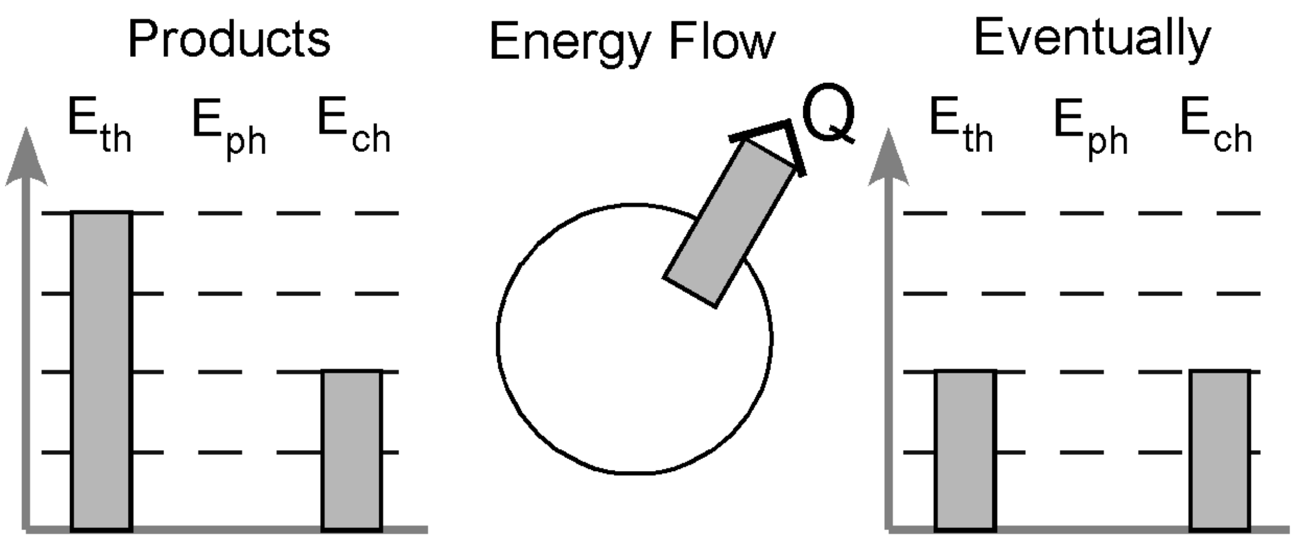
- $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ + energy
  - Place energy bars for E_{ch}
  - Let's first ignore energy required to initiate reaction.
    - Like consideration of the motion of a ball the moment it begins to roll downhill - don't worry about initial push.



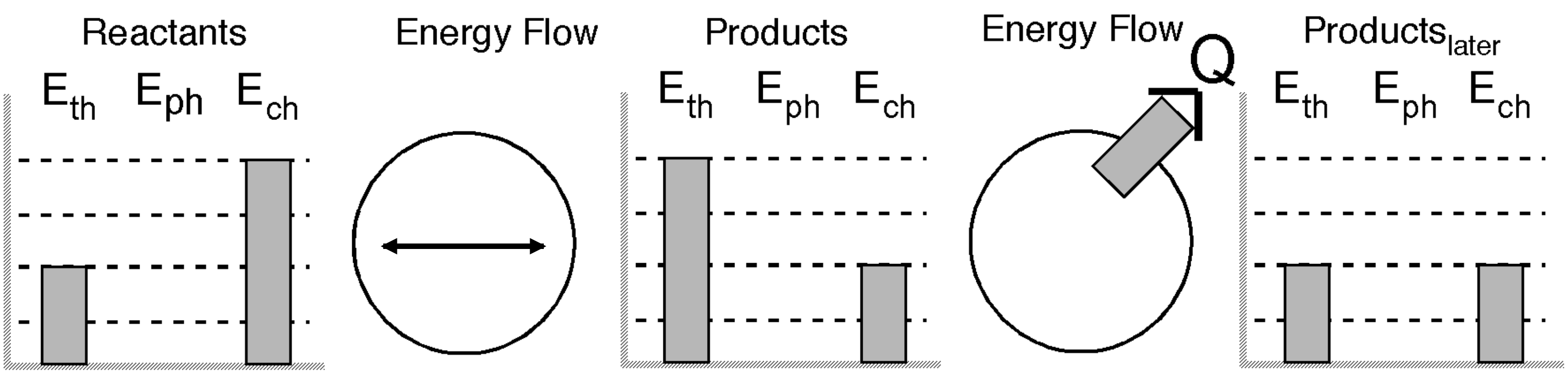
- Now take into account changes in E_{th}
  - When reactant molecules collide to produce products that store *less* energy, new molecules move away *more* rapidly



- System is now hotter than surroundings; energy flows out of system until thermal equilibrium is re-established



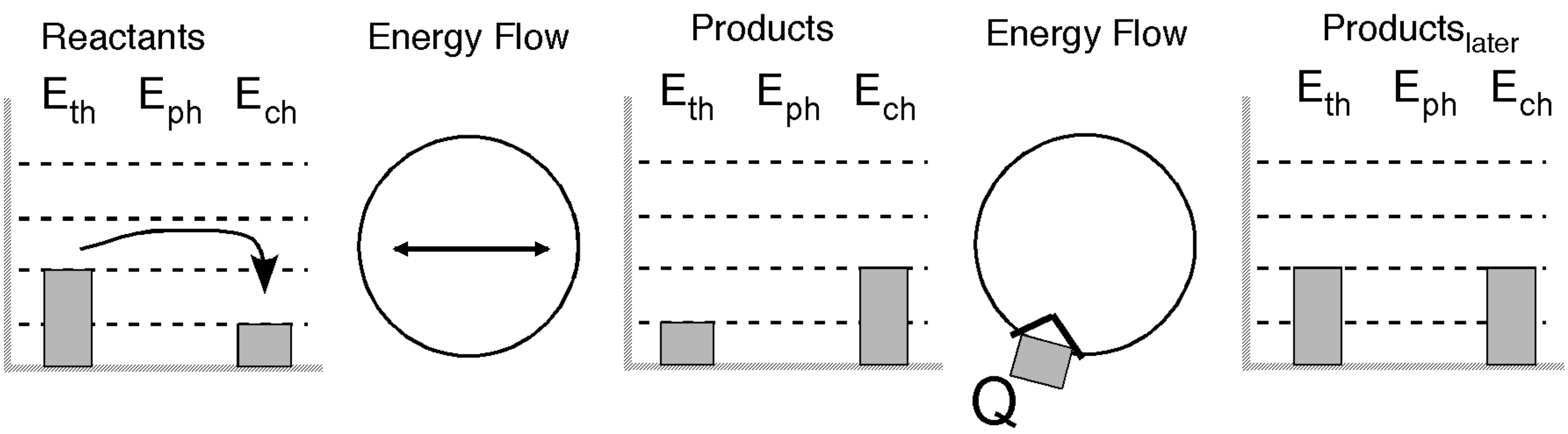
1. Decrease in E_{ch} results in increased E_{th}
2. System is now hotter than surroundings
3. Energy eventually moves from system to surroundings via heating



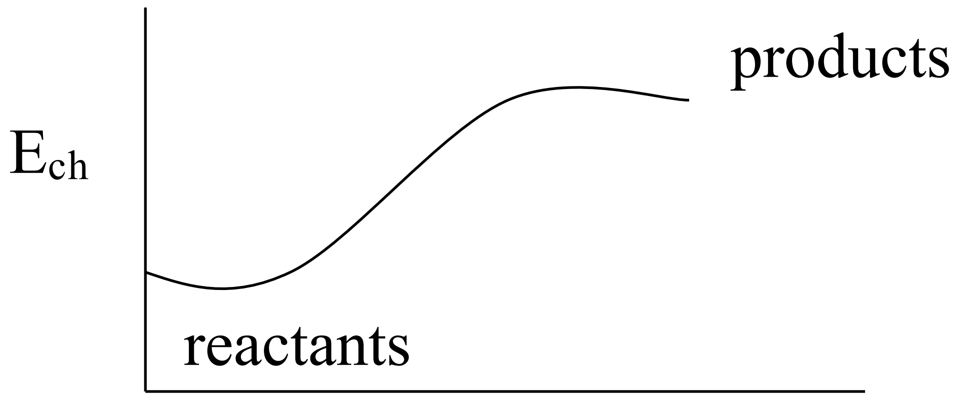
- How does the energy used to *start the reaction* compare to energy released *as the reaction proceeds*?
- It is really negligible so we will ignore it for now

- When NH_4Cl dissolves in water, the resulting solution gets much colder
- What caused the E_{th} to decrease?
  - Some E_{th} of water required to separate ions in crystal lattice.
  - Resulting solution has greater E_{ch} than before

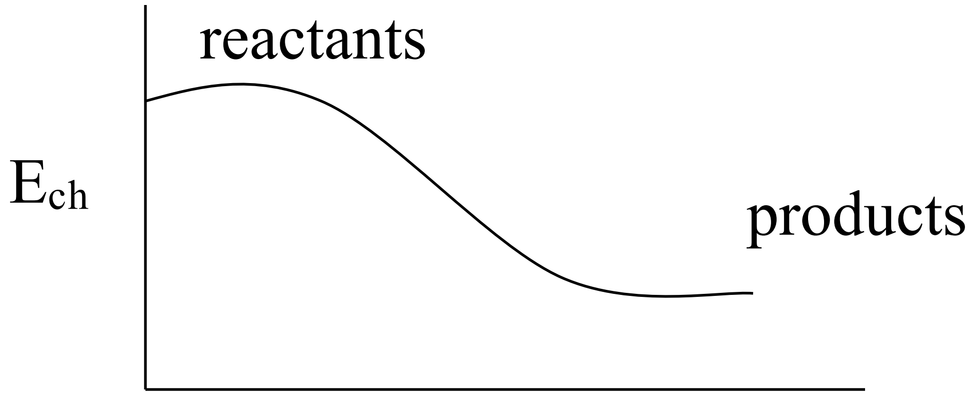
- The system trades E_{th} for E_{ch}
- Eventually energy enters cooler system from warmer surroundings (you!)



- Endo



- Exo



- Unit 6 worksheet 4

- ***Chemical reactions involve the rearrangement of atoms in molecules to form new molecules.***
- ***This rearrangement of atoms results in a change in the chemical potential energy (Ech) of the system.***
- ***This invariably produces changes in thermal energy (Eth), and results in energy transfers between system and surroundings.***

- **Mass is conserved** because the atoms in the products are the same as those found in the reactants. This is represented symbolically as a **balanced chemical equation**.
- Because the grouping of atoms into molecules is changed in a chemical reaction, the total number of molecules (or formula units) in the products need **not** be the same as that in the reactants.
- Substances store varying amounts of **chemical potential energy** (Ech) **due to the arrangement** of atoms.

- It is not possible to measure this amount of energy directly. However, rearrangement of atoms during reaction produces changes in Eth; the resulting energy transfers (as Q) between system and surroundings can be measured.
- From these one can deduce differences in the Ech of reactants and products.
- Energy bar graphs are a useful tool for accounting for energy (stored and transferred) during chemical change.