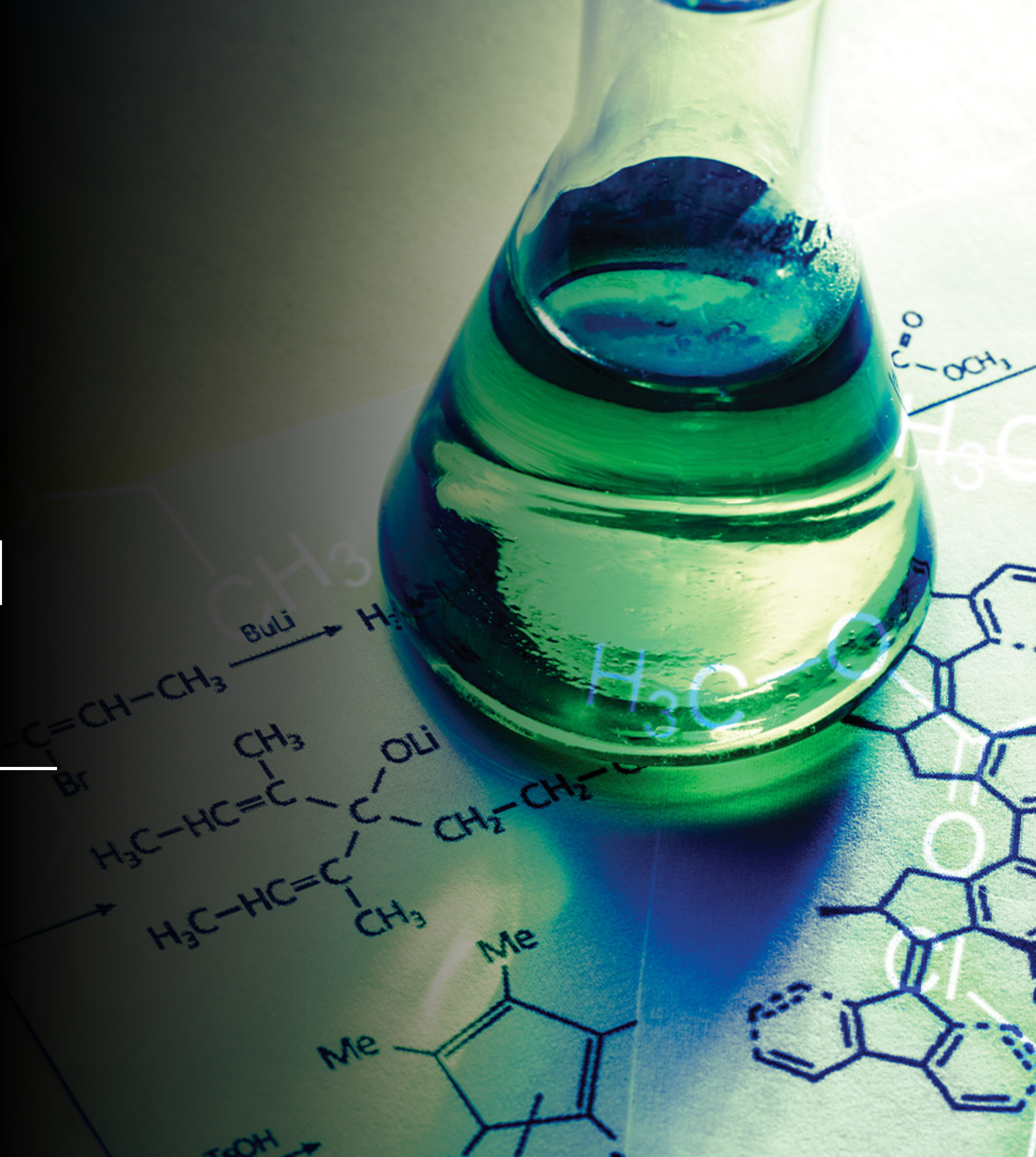
Chemical Energy



John Dalton (1766 - 1844)

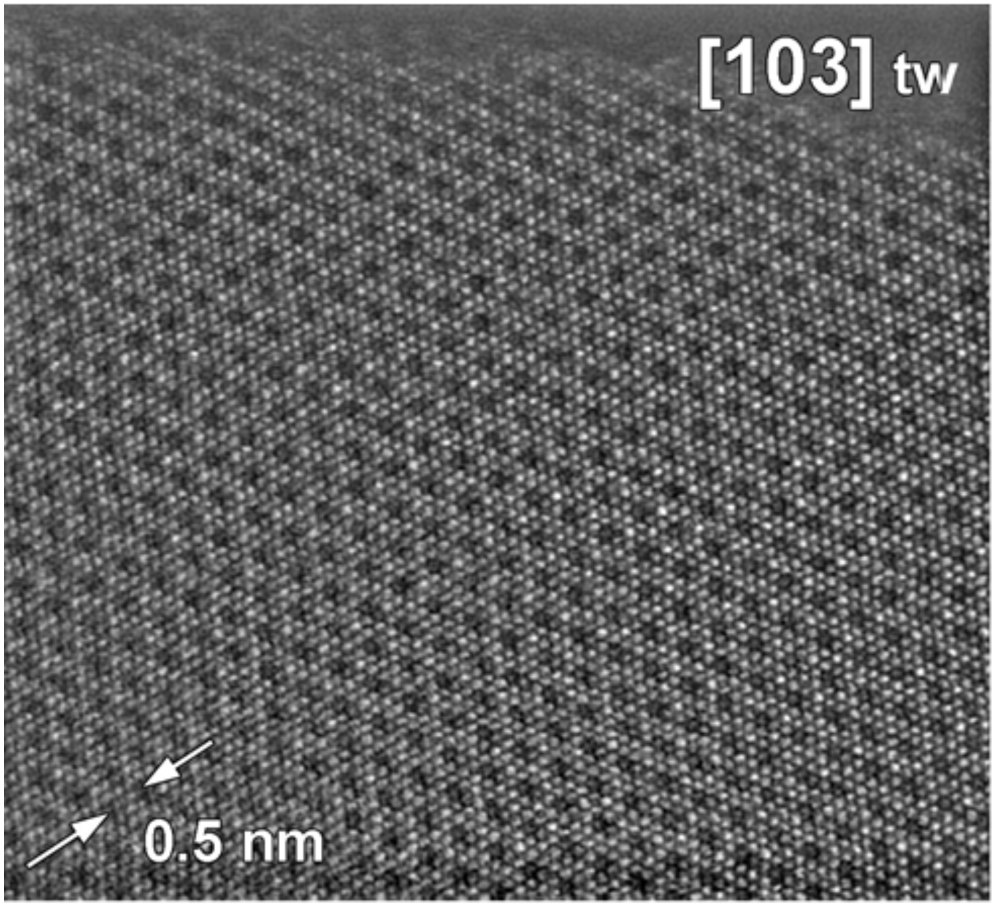
- Stoichiometry – math of how elements combined to form other elements
- Dalton found that oxygen & carbon combined to make 2 compounds (1803)
  - Each had its own particular weight ratio of oxygen to carbon (1.33:1 and 2.66:1)
  - Same amount of carbon, one had exactly twice as much oxygen as the other
- Law of simple multiple proportions

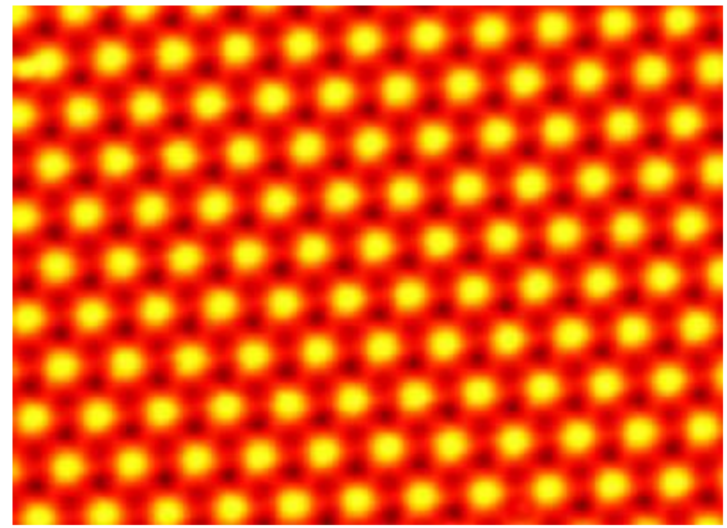
Dalton's Elementary Atomic Theory

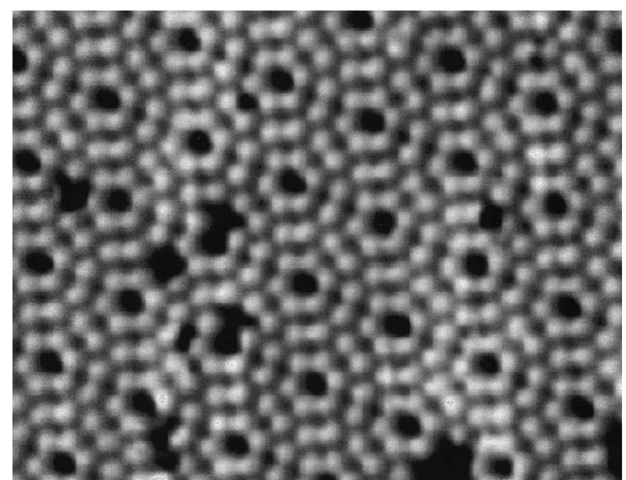
- Elements are made of extremely small particles called atoms
- Atoms of a given element are identical in size, mass, and other properties
- Atoms of different elements differ in size, mass, and other properties
- Atoms cannot be subdivided, created, or destroyed
- Atoms of different elements combine in simple whole-number ratios to form chemical compounds
- In chemical reactions, atoms are combined, separated, or rearranged.

Dalton's Elementary Atomic Theory

- Elements are made of extremely small particles called atoms.

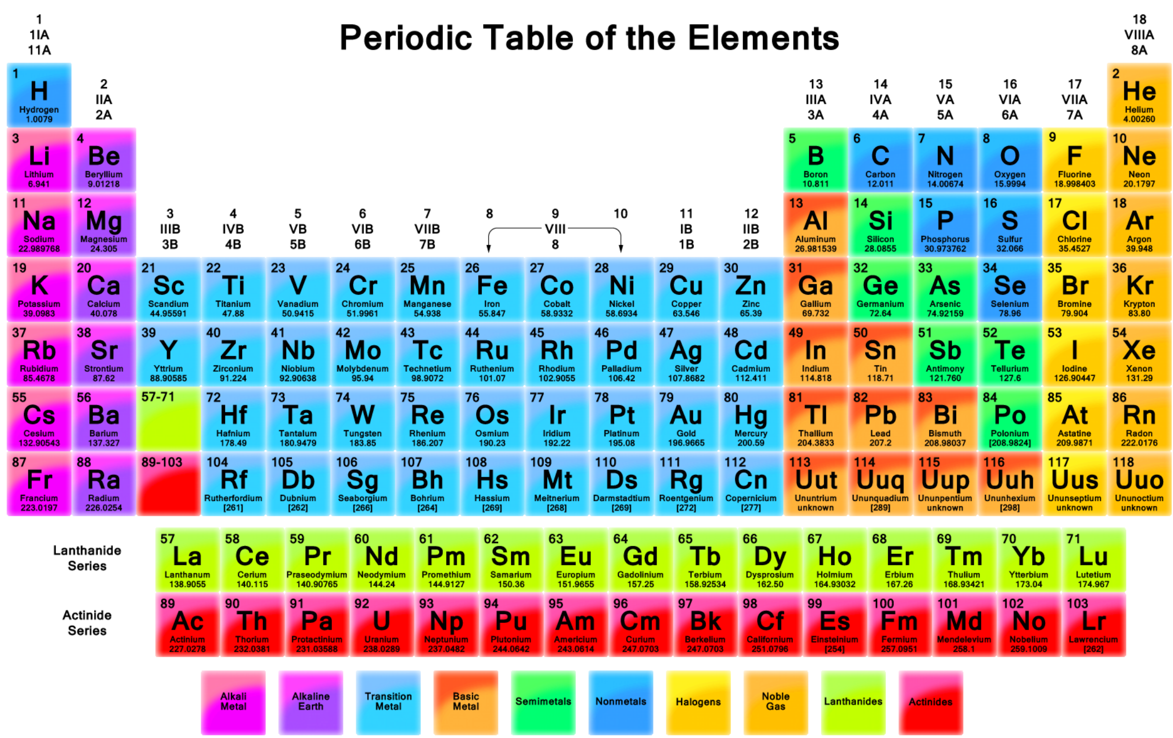






Dalton's Elementary Atomic Theory

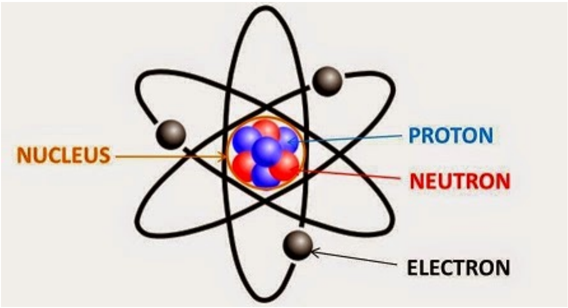
- Atoms of a given element are identical in size, mass, and other properties.
- Atoms of different elements differ in size, mass, and other properties.



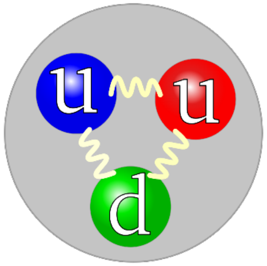
Dalton's Elementary Atomic Theory

- Atoms cannot be subdivided, created, or destroyed.

- As we saw with the talks on Atomic and Nuclear energy, this assertion is false.
  - Atoms are made of protons, neutrons, and electrons

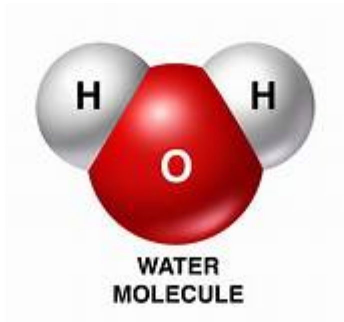


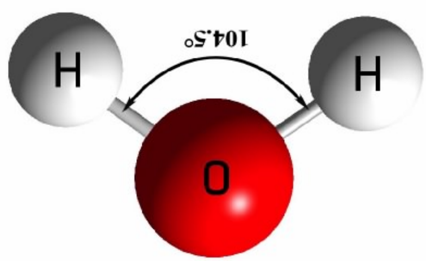
  - Protons and neutrons are made of quarks



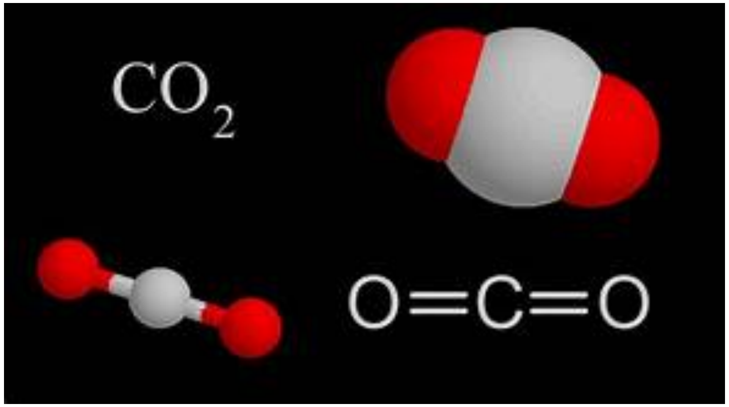
Dalton's Elementary Atomic Theory

- Atoms of different elements combine in simple whole-number ratios to form chemical compounds.
- Let's look at two common molecules:
  - Water





  - Carbon Dioxide



Dalton's Elementary Atomic Theory

- A chemical reaction is one in which various chemicals, elements, or species react to one another in one of three ways.

- The reactants are the species that start the reaction and the products are the result of the chemical reaction.

- Three common types of reactions:
  - Precipitation
    - Dissolved substances react to form one or more solid products
  - Acid-base
    - Hydrogen ion is transferred rom one chemical species to another
  - Oxidation-reduction
    - A reaction involving the transfer of O_2 molecules

Dalton's Elementary Atomic Theory

- A balanced chemical equation provides a great deal if information about the interaction of various species.
- Chemical formulas provide the identities of each reactant and product in a chemical reaction.
- Coefficients provide the relative numbers of each species allowing for quantitative assessment of the relationships.
- Stoichiometry is the quantitative part of the relationships.

Concept Question

What does it mean to say an equation is balanced?

a) An equation is balanced when the same number of each element is represented on the reactant and product sides.

b) An equation is balanced when the same number of each molecules are represented on the reactant and product sides.

c) An equation is balanced when the same number of reactants are represented on the product sides.

d) An equation is balanced when the same number of molecule and atom is represented on the reactant and product sides.

Dalton's Elementary Atomic Theory

- In chemical reactions, atoms are combined, separated, or rearranged.

- An example of chemical reaction using stoichiometry:
  - $P_4 + O_2 \rightarrow P_4O_{10}$

Dalton's Elementary Atomic Theory

- In chemical reactions, atoms are combined, separated, or rearranged.

- An example of chemical reaction using stoichiometry:
  - $P_4 + O_2 \rightarrow P_4O_{10}$
  - I need to get the same number of Phosphorus (P) and Oxygen (O) atoms on both side.
  - There are four P on both side, which is good.

Dalton's Elementary Atomic Theory

- In chemical reactions, atoms are combined, separated, or rearranged.

- An example of chemical reaction using stoichiometry:
  - $P_4 + O_2 \rightarrow P_4O_{10}$
  - I need to get the same number of Phosphorus (P) and Oxygen (O) atoms on both side.
  - There are four P on both side, which is good.
  - But there are 2 O on one side and 10 on the other. To balance them I need to get 10 on both sides. To do that I need to add a 5.
  - $P_4 + \mathbf{5}O_2 \rightarrow P_4O_{10}$

Example Problem

Balance the chemical reactions shown below:

$H_2 + I_2 \rightarrow HI$

$Fe + H_2O \rightarrow Fe_3O_4 + H_2$

Example Problem

Balance the chemical reactions shown below:

$H_2 + I_2 \rightarrow HI$

> Notice that on the left there are two hydrogens and two iodine atoms. So on the right there have to be two of each. In order for this to happen, and still maintain the outcome of an HI molecule:
>
> $H_2 + I_2 \rightarrow$ **2**HI

$Fe + H_2O \rightarrow Fe_3O_4 + H_2$

Example Problem

Balance the chemical reactions shown below:

$H_2 + I_2 \rightarrow HI$

Notice that on the left there are two hydrogens and two iodine atoms. So on the right there have to be two of each. In order for this to happen, and still maintain the outcome of an HI molecule:

$H_2 + I_2 \rightarrow \mathbf{2}HI$

$Fe + H_2O \rightarrow Fe_3O_4 + H_2$

We need the same number of each element without changing the reaction. I need 4 oxygen molecules:

$Fe + \mathbf{4}H_2O \rightarrow Fe_3O_4 + H_2$

Example Problem

Balance the chemical reactions shown below:

$H_2 + I_2 \rightarrow HI$

Notice that on the left there are two hydrogens and two iodine atoms. So on the right there have to be two of each. In order for this to happen, and still maintain the outcome of an HI molecule:

$H_2 + I_2 \rightarrow \mathbf{2}HI$

$Fe + H_2O \rightarrow Fe_3O_4 + H_2$

We need the same number of each element without changing the reaction. I need 4 oxygen molecules:

$Fe + \mathbf{4}H_2O \rightarrow Fe_3O_4 + H_2$

Now we need to get 3 iron on each side

$\mathbf{3}Fe + \mathbf{4}H_2O \rightarrow Fe_3O_4 + H_2$

Example Problem

Balance the chemical reactions shown below:

$H_2 + I_2 \rightarrow HI$

Notice that on the left there are two hydrogens and two iodine atoms. So on the right there have to be two of each. In order for this to happen, and still maintain the outcome of an HI molecule:

$H_2 + I_2 \rightarrow \mathbf{2}HI$

$Fe + H_2O \rightarrow Fe_3O_4 + H_2$

We need the same number of each element without changing the reaction. I need 4 oxygen molecules:

$Fe + \mathbf{4}H_2O \rightarrow Fe_3O_4 + H_2$

Now we need to get 3 iron on each side

$\mathbf{3}Fe + \mathbf{4}H_2O \rightarrow Fe_3O_4 + H_2$

And finally we need to get 8 hydrogens on both sides

$\mathbf{3}Fe + \mathbf{4}H_2O \rightarrow Fe_3O_4 + \mathbf{4}H_2$

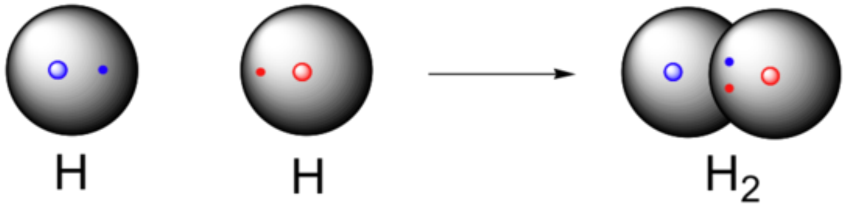
What is chemical energy and where is it stored?

- Chemical energy - the potential of a substance to undergo a chemical reaction
- Chemical energy is stored in the bonds between different atoms within molecules
- Breaking or making chemical bonds involves the use of energy which may either be absorbed or emitted during the reaction

What are the different types of chemical bonds?

Covalent bonds

- A bond that forms due to a mutual attraction of atoms for a shared pair of electrons.
- Both atoms must have tendency to attract electrons to themselves.
- An example is molecular hydrogen (H_2)

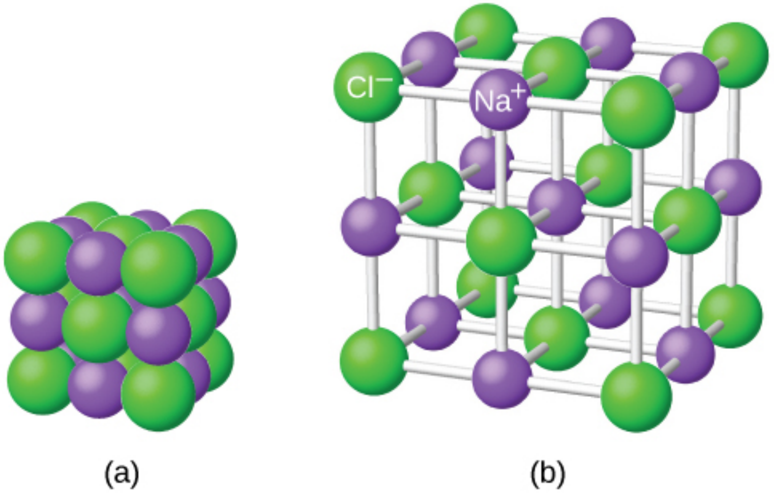


What are the different types of chemical bonds?

Ionic bonds

- The bonds between ions in compounds typically known as ionic compounds or salts.
- Electrostatic attraction of oppositely charged ions by transfer of electrons

- An example of one is Sodium Chloride (NaCl) or common table salt



What are the different types of chemical bonds?

- Metallic bonds

- A bond that form from the electrostatic attractive force between conduction electrons and positively charged metal ions

- Accounts for many of the physical properties of metals

- An example are ion alloys

More on Chemical Reactions

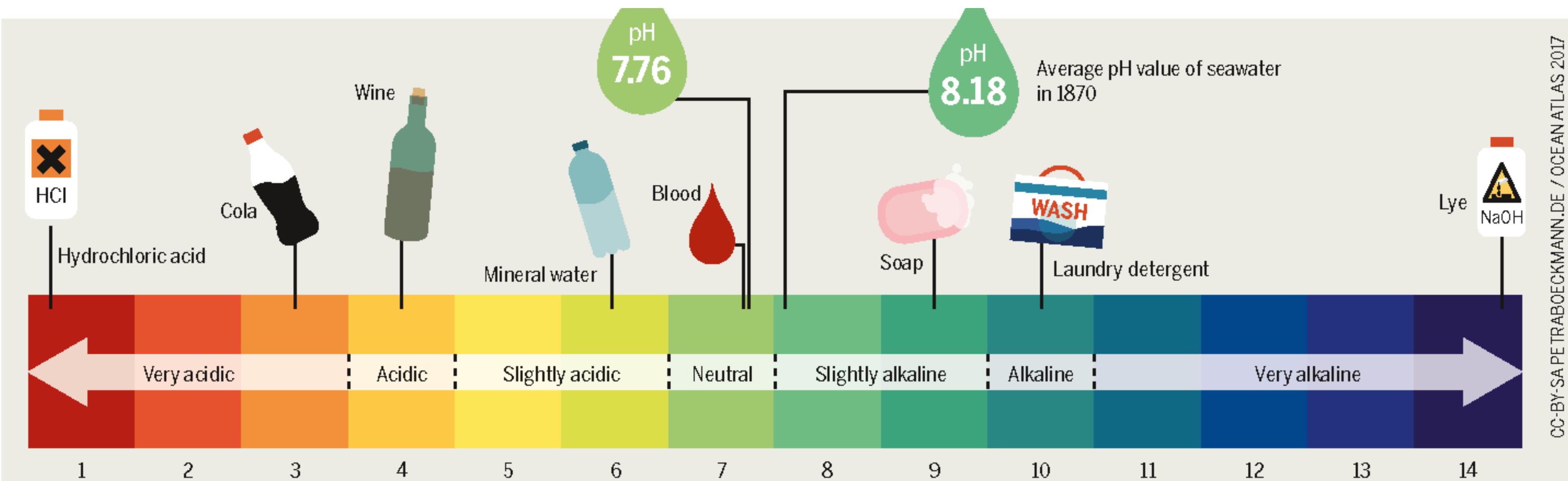
pH Scale

- Every aqueous solution contains both hydroxide (OH^-) and hydronium (H_3O^+).
- The amount of hydronium in a system determines where a substance exists on the pH scale.
- Defined as $pH = -\log[H_3O^+]$

Concentration of Hydrogen ions compared to distilled water		Examples
10,000,000	pH 0	Battery acid
1,000,000	pH 1	Hydrochloric acid
100,000	pH 2	Lemon juice, vinegar
10,000	pH 3	Grapefruit, soft drink
1,000	pH 4	Tomato juice, acid rain
100	pH 5	Black coffee
10	pH 6	Urine, saliva
1	pH 7	"Pure" water
1/10	pH 8	Sea water
1/100	pH 9	Baking soda,
1/1,000	pH 10	Great Salt Lake
1/10,000	pH 11	Ammonia solution
1/100,000	pH 12	Soapy water
1/1,000,000	pH 13	Bleach
1/10,000,000	pH 14	Liquid drain cleaner

More on Chemical Reactions

- When a substance has more hydronium it is called an acid.
- When a substance has more hydroxide is called a base
- When a substance has equal amounts of hydronium and hydroxide is neutral.



Concept Question

What is the difference between acids and bases?

a) An acid donates a hydrogen atom and a base will receive a hydrogen atom.

b) A base donates a hydrogen atom and an acid will receive a hydrogen atom.

c) An acid donates a hydrogen ion and a base will receive a hydrogen ion.

d) A base donates a hydrogen ion and an acid will receive a hydrogen ion.

Example Problem

Using the table below identify if the substance is slightly acidic, acidic, strongly acidic, slightly basic, basic, strongly basic, or neutral.

Substance	pH Scale	Acid, base or neutral
Hand Soap	9.5	
Coca Cola	2.5	
Water	7	
Red Bull	3.4	
Evian water	8.1	
Bleach	12.5	
Milk	6.8	

Example Problem

Using the table below identify if the substance is slightly acidic, acidic, strongly acidic, slightly basic, basic, strongly basic, or neutral.

Substance	pH Scale	Acid, base or neutral
Hand Soap	9.5	Basic
Coca Cola	2.5	Strongly Acidic
Water	7	
Red Bull	3.4	
Evian water	8.1	
Bleach	12.5	
Milk	6.8	

Example Problem

Using the table below identify if the substance is slightly acidic, acidic, strongly acidic, slightly basic, basic, strongly basic, or neutral.

Substance	pH Scale	Acid, base or neutral
Hand Soap	9.5	Basic
Coca Cola	2.5	Strongly Acidic
Water	7	Neutral
Red Bull	3.4	Acidic
Evian water	8.1	Slightly Basic
Bleach	12.5	Strongly Basic
Milk	6.8	Slightly Acidic