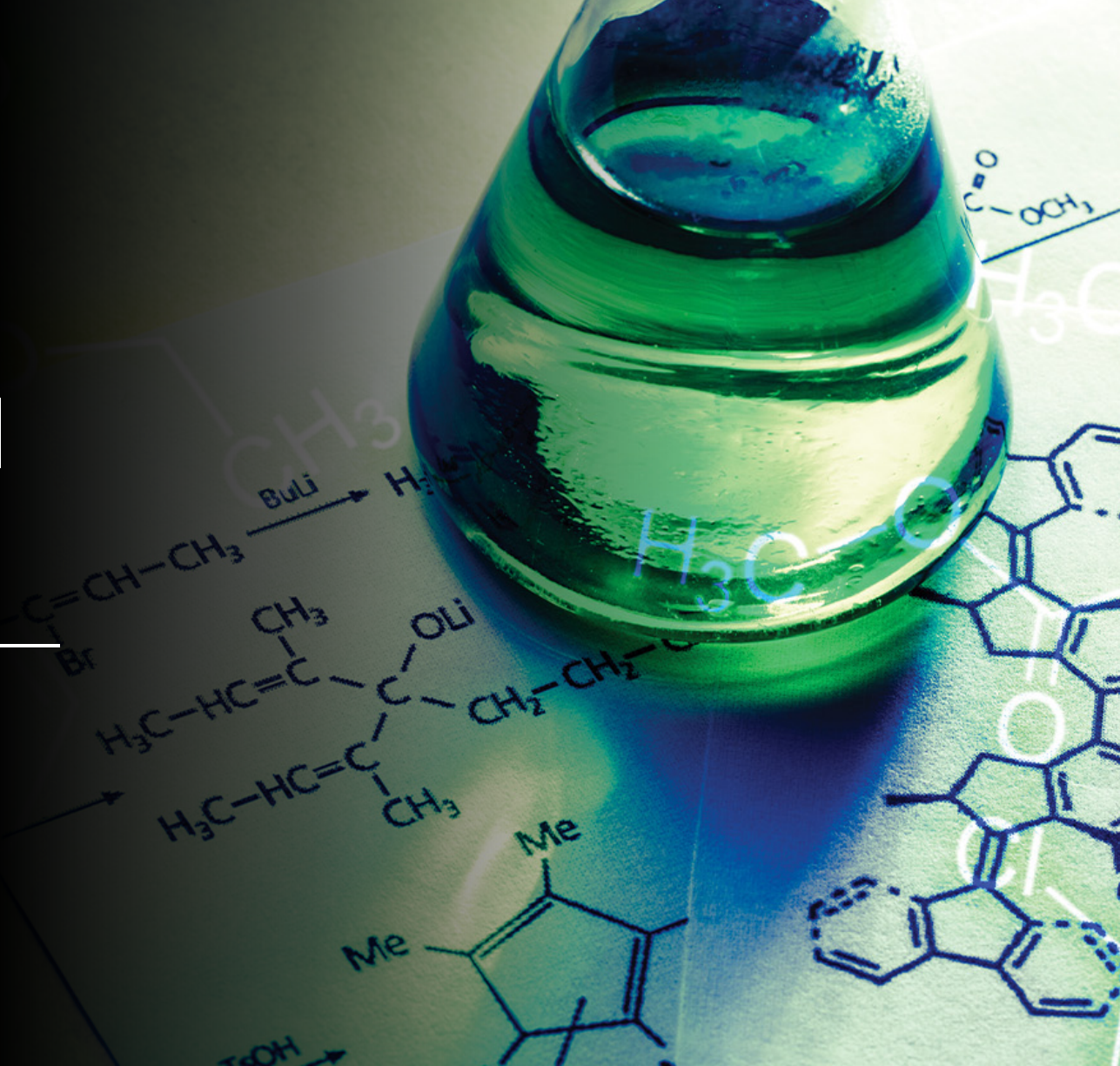




Chemical Energy



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

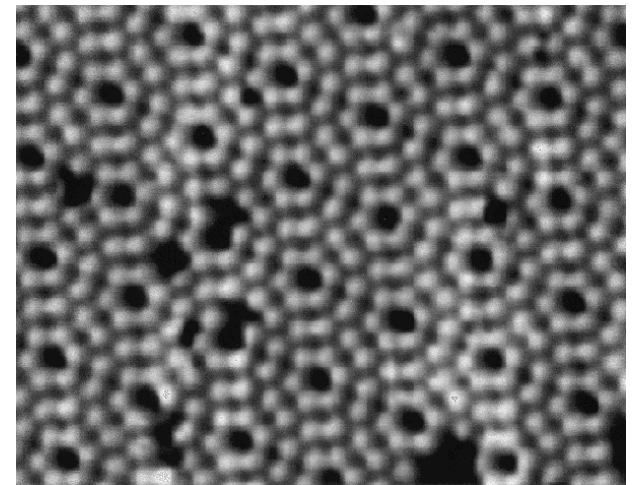
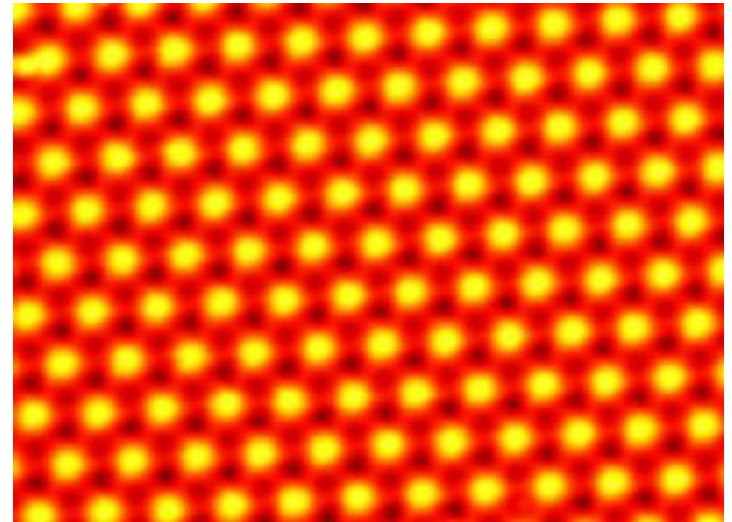
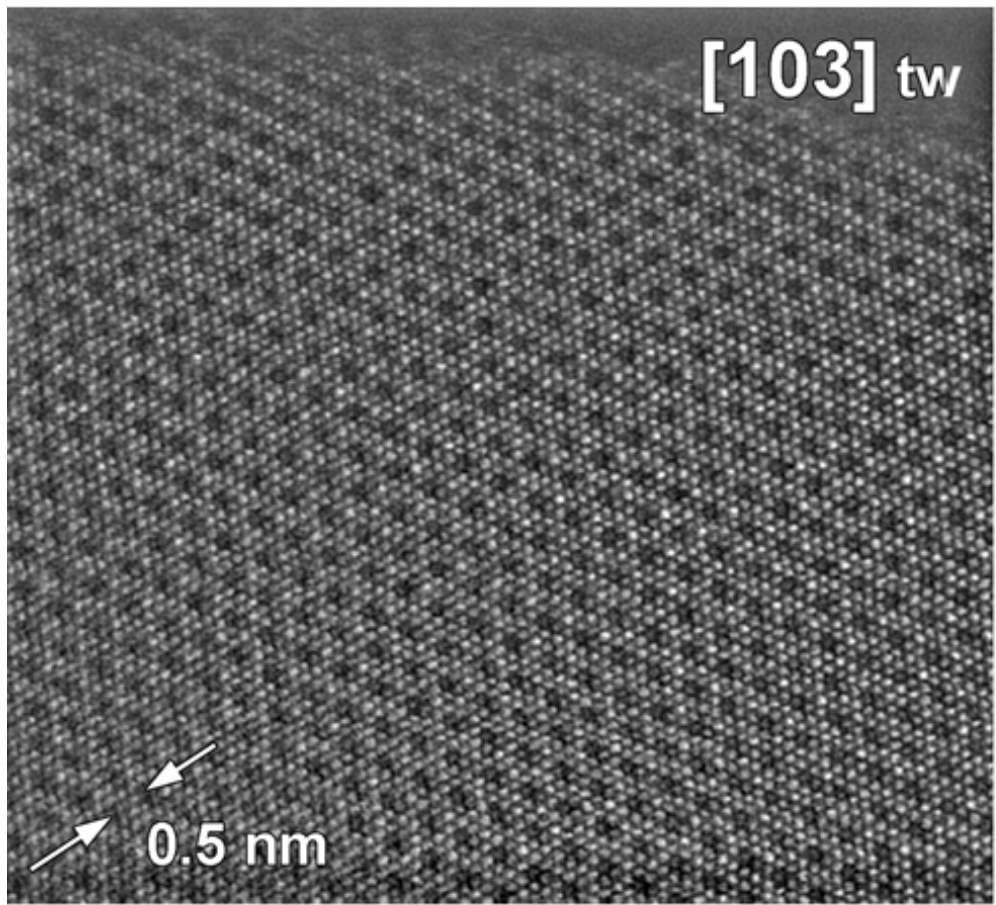


Dalton's Elementary Atomic Theory

- 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

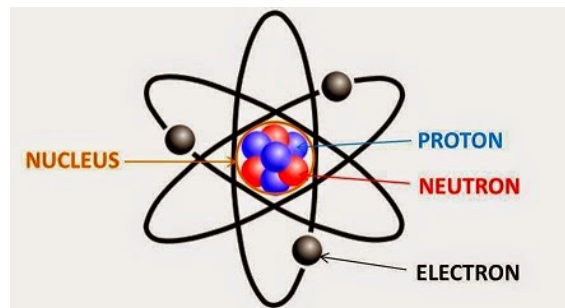
- Atoms of a given element are identical in size, mass, and other properties.
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Periodic Table of the Elements

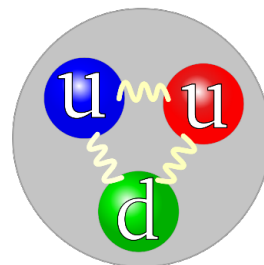
1 1IA 11A																	18 VIIIA 8A
1 H Hydrogen 1.0079	2 IIA 2A											13 IIIA 3A	14 IVA 4A	15 VA 5A	16 VIA 6A	17 VIIA 7A	2 He Helium 4.00260
3 Li Lithium 6.941	4 Be Beryllium 9.01218											5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.00674	8 O Oxygen 15.9994	9 F Fluorine 18.998403	10 Ne Neon 20.1797
11 Na Sodium 22.989768	12 Mg Magnesium 24.305	3 IIIB 3B	4 IVB 4B	5 VB 5B	6 VIB 6B	7 VIIB 7B	8 VIII 8	9 VIII 8	10 VIII 8	11 IB 1B	12 IIB 2B	13 Al Aluminum 26.981539	14 Si Silicon 28.0855	15 P Phosphorus 30.973762	16 S Sulfur 32.066	17 Cl Chlorine 35.4527	18 Ar Argon 39.948
19 K Potassium 39.0983	20 Ca Calcium 40.078	21 Sc Scandium 44.95591	22 Ti Titanium 47.88	23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.938	26 Fe Iron 55.847	27 Co Cobalt 58.9332	28 Ni Nickel 58.6934	29 Cu Copper 63.546	30 Zn Zinc 65.39	31 Ga Gallium 69.732	32 Ge Germanium 72.64	33 As Arsenic 74.92159	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.80
37 Rb Rubidium 85.4678	38 Sr Strontium 87.62	39 Y Yttrium 88.90585	40 Zr Zirconium 91.224	41 Nb Niobium 92.90638	42 Mo Molybdenum 95.94	43 Tc Technetium 98.9072	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.9055	46 Pd Palladium 106.42	47 Ag Silver 107.8682	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.71	51 Sb Antimony 121.760	52 Te Tellurium 127.6	53 I Iodine 126.90447	54 Xe Xenon 131.29
55 Cs Cesium 132.90543	56 Ba Barium 137.327	57-71 Lanthanide Series	72 Hf Hafnium 178.49	73 Ta Tantalum 180.9479	74 W Tungsten 183.85	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.9665	80 Hg Mercury 200.59	81 Tl Thallium 204.3833	82 Pb Lead 207.2	83 Bi Bismuth 208.98037	84 Po Polonium [208.9824]	85 At Astatine 209.9871	86 Rn Radon 222.0176
87 Fr Francium 223.0197	88 Ra Radium 226.0254	89-103 Actinide Series	104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Seaborgium [266]	107 Bh Bohrium [264]	108 Hs Hassium [289]	109 Mt Meitnerium [288]	110 Ds Darmstadtium [289]	111 Rg Roentgenium [272]	112 Cn Copernicium [277]	113 Uut Ununtrium unknown	114 Uuq Ununquadium [289]	115 Uup Ununpentium unknown	116 Uuh Ununhexium [288]	117 Uus Ununseptium unknown	118 Uuo Ununoctium unknown
		57 La Lanthanum 138.9055	58 Ce Cerium 140.115	59 Pr Praseodymium 140.90765	60 Nd Neodymium 144.24	61 Pm Promethium 144.9127	62 Sm Samarium 150.36	63 Eu Europium 151.9655	64 Gd Gadolinium 157.25	65 Tb Terbium 158.92534	66 Dy Dysprosium 162.50	67 Ho Holmium 164.93032	68 Er Erbium 167.26	69 Tm Thulium 168.93421	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.967	
		89 Ac Actinium 227.0278	90 Th Thorium 232.0381	91 Pa Protactinium 231.03688	92 U Uranium 238.0289	93 Np Neptunium 237.0482	94 Pu Plutonium 244.0642	95 Am Americium 243.0614	96 Cm Curium 247.0703	97 Bk Berkelium 247.0703	98 Cf Californium 251.0796	99 Es Einsteinium [254]	100 Fm Fermium 257.0951	101 Md Mendelevium 258.1	102 No Nobelium 259.1009	103 Lr Lawrencium [262]	
Alkali Metal	Alkaline Earth	Transition Metal	Basic Metal	Semimetals	Nonmetals	Halogens	Noble Gas	Lanthanides	Actinides								

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



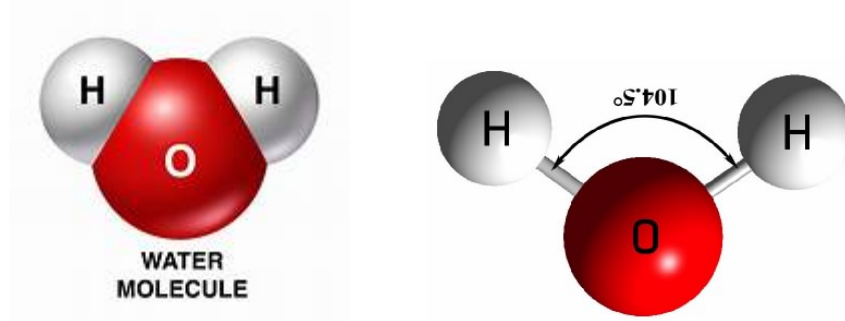
- Protons and neutrons are made of quarks



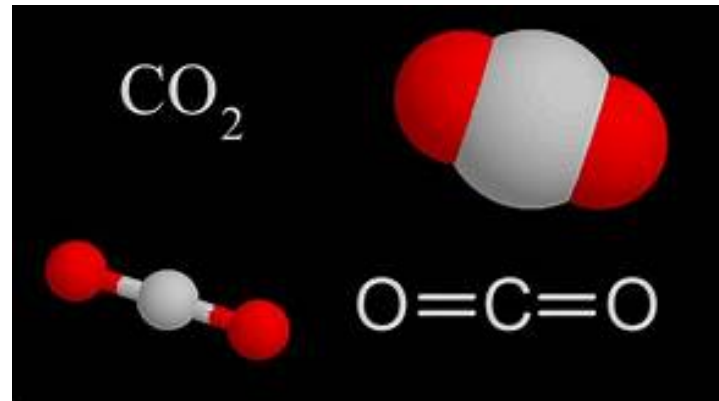
Dalton's Elementary Atomic Theory

- 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 from 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 of 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

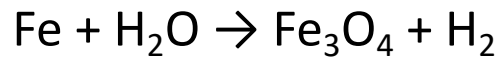
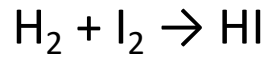
- In chemical reactions, atoms are combined, separated, or rearranged.
- An example of chemical reaction using stoichiometry:
 - $P_4 + O_2 \rightarrow P_4O_{10}$
 - I need to get the same number of Phosphorus (P) and Oxygen (O) atoms on both side.
 - There are four P on both side, which is good.

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.
 - $P_4 + 5O_2 \rightarrow P_4O_{10}$

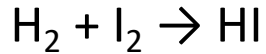
Example Problem

Balance the chemical reactions shown below:

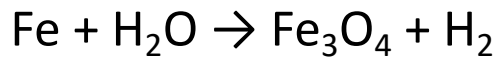
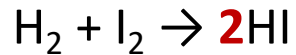


Example Problem

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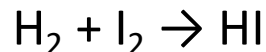


Notice that on the left there are two hydrogens and two iodine atoms. So on the right there have to be two of each. In order for this to happen, and still maintain the outcome of an HI molecule:

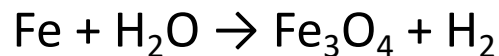
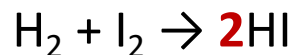


Example Problem

Balance the chemical reactions shown below:



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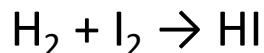


We need the same number of each element without changing the reaction. I need 4 oxygen molecules:

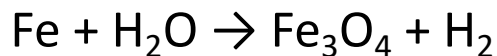
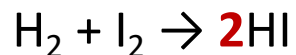


Example Problem

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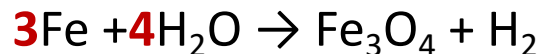
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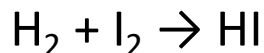


Now we need to get 3 iron on each side

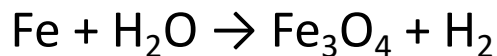
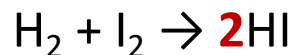


Example Problem

Balance the chemical reactions shown below:



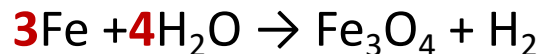
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We need the same number of each element without changing the reaction. I need 4 oxygen molecules:



Now we need to get 3 iron on each side



And finally we need to get 8 hydrogens on both sides



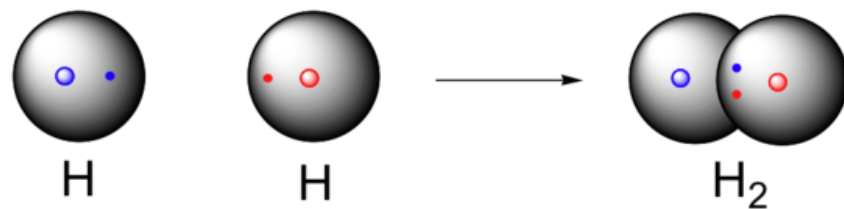
What is chemical energy and where is it stored?

- 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

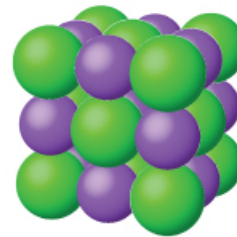
- A bond that forms due to a mutual attraction of atoms for a shared pair of electrons.
- Both atoms must have tendency to attract electrons to themselves.
- An example is molecular hydrogen (H_2)



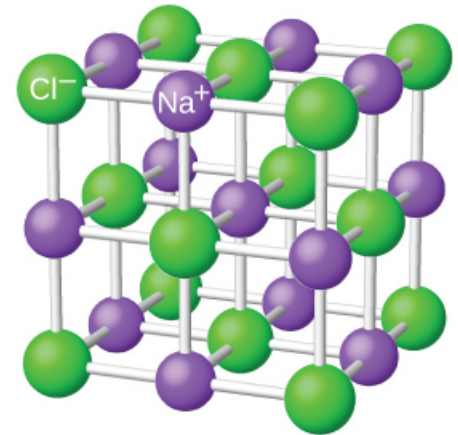
What are the different types of chemical bonds?

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



(a)



(b)

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

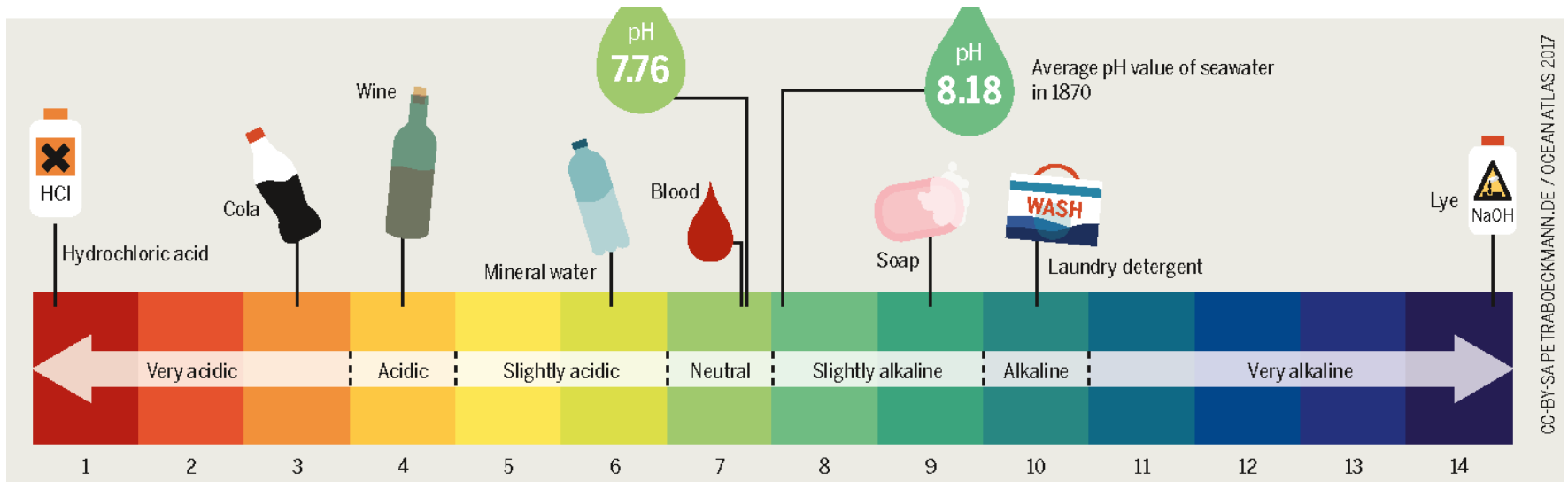
pH Scale

- 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 $\text{pH} = -\log[\text{H}_3\text{O}^+]$

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	

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Water	7	Neutral
Red Bull	3.4	Acidic
Evian water	8.1	Slightly Basic
Bleach	12.5	Strongly Basic
Milk	6.8	Slightly Acidic