Ch02

Elements

How searching for fire and air

revealed 118 flavors of atom.

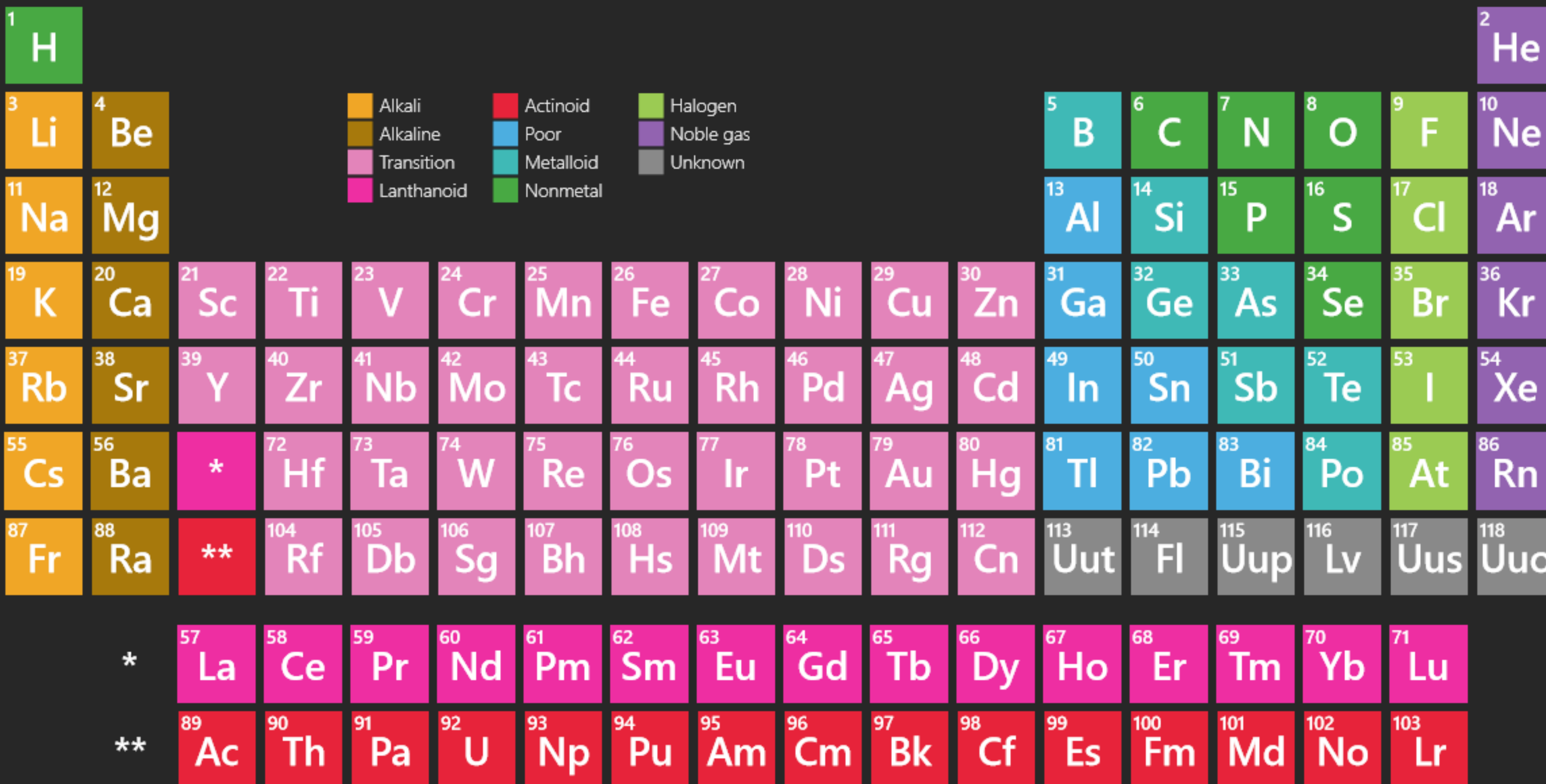
version 1.5

Man has been asking himself what is the most fundamental matter since day one.

About two and a half millennia ago we decided there were four elements.

Periodic Table

In December 2015 that number rose to 118.
Today we're going to talk about how
we made the trip, about what makes something
elemental and why it's important.



The Elements

- Scientific Method
  - The iterative nature of theory.
- The Greek Contribution
  - Atomic Theory 1.0
    - The idea of Atoms
  - Elemental Theory
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  - Discovery of Oxygen
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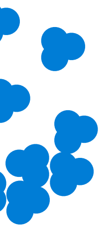

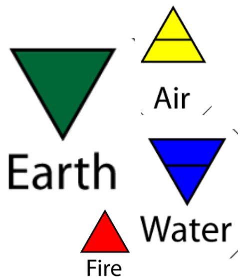

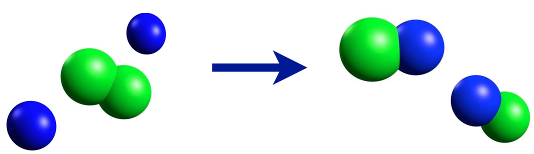

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    - the mole & molar mass
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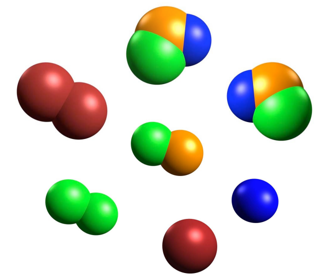

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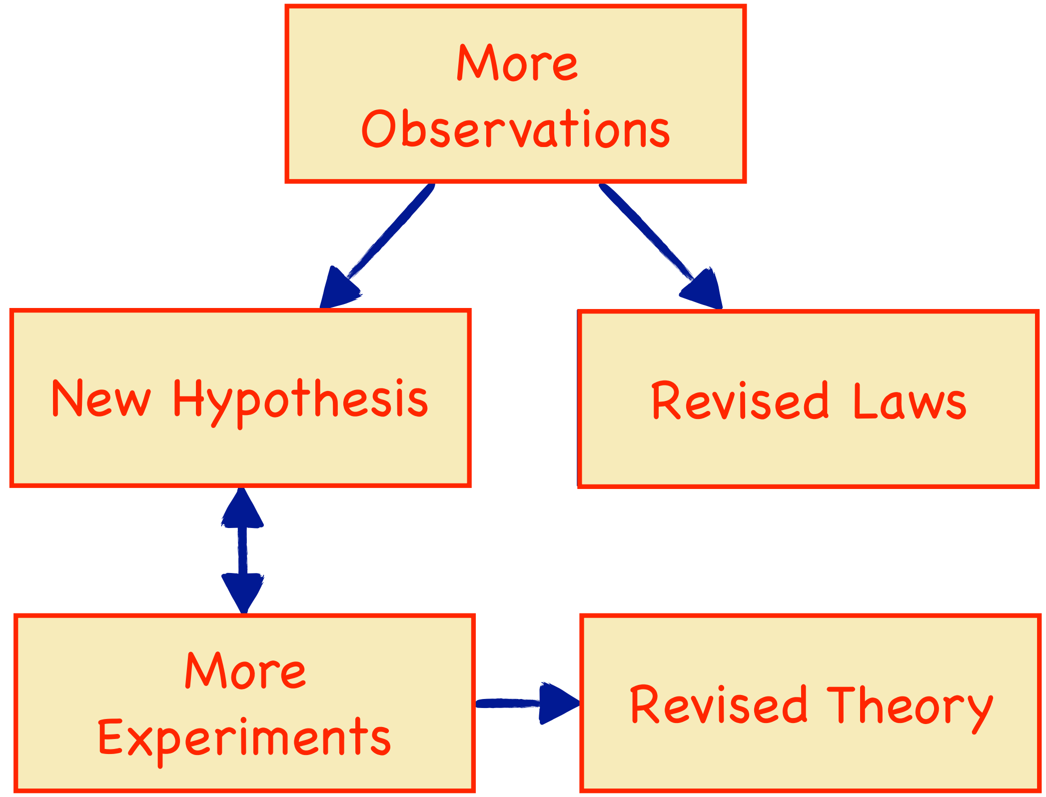
Scientific Method is Iterative

- The products of scientific method are laws and theories.
  - These laws and theories are based on the observations available at the time they're produced.
  - As time moves forward we explore further.
    - We take a more detailed look.
    - Or consider new applications.
  - Which brings up new questions and allows new observations.
  - Last years theory – which was "good enough" for many things – may not explain all our new observations.
    - So we offer new explanations (hypothesis) and experiment to disprove or improve them.
  - New research produces revised theories and improved laws.



Ch02

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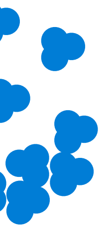

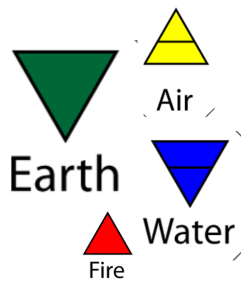

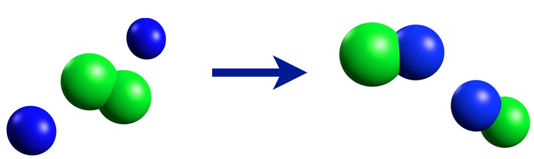

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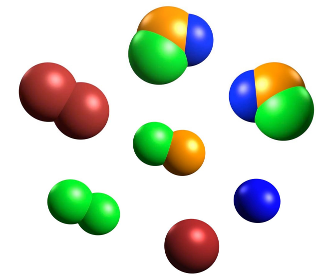

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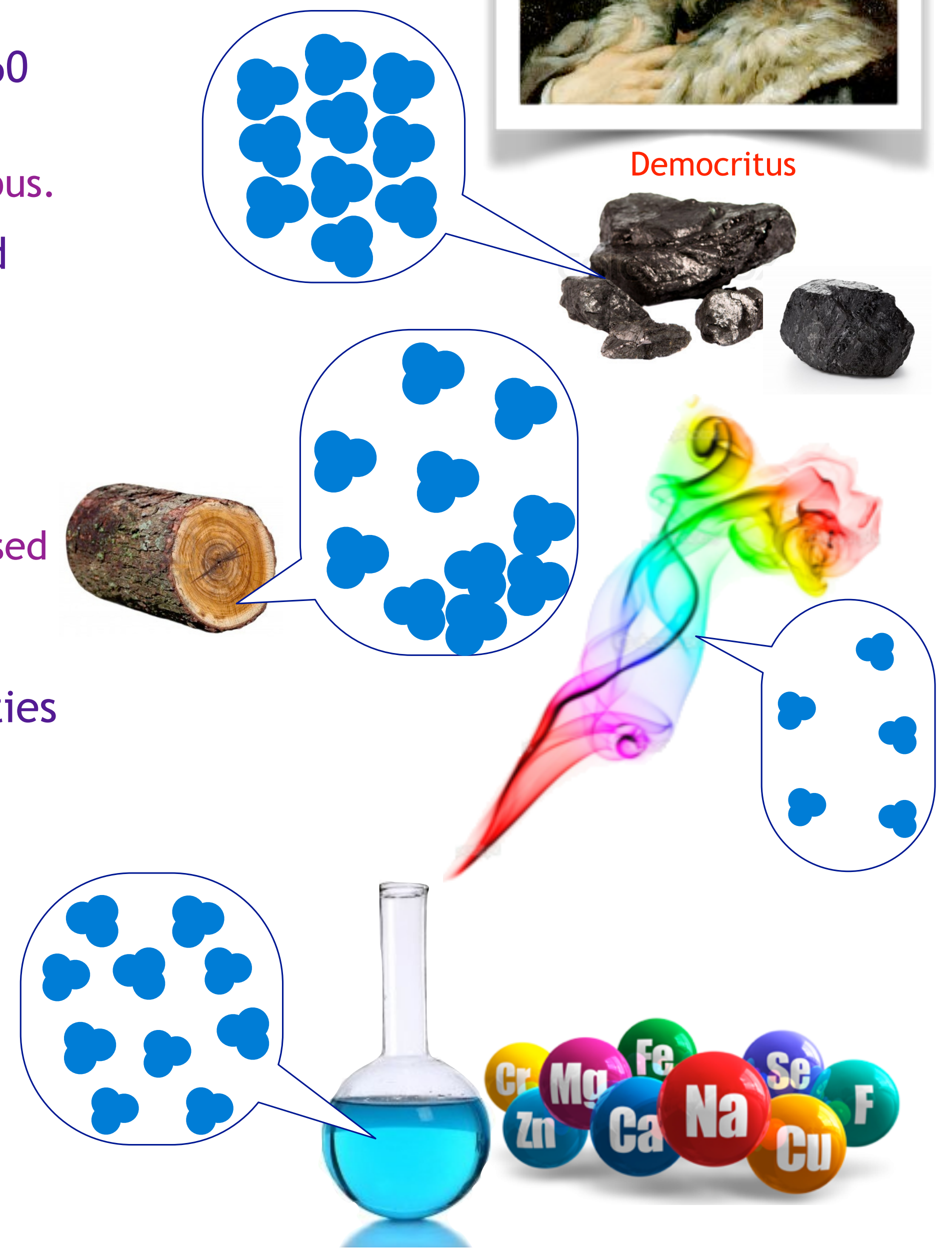
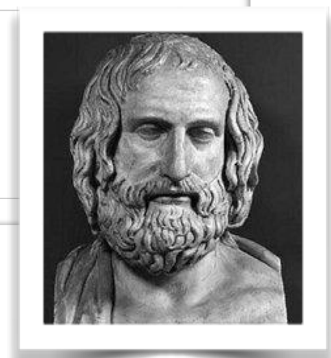
Atomic Theory

- The earliest concept of the atom came from the Greek philosopher/scientist Democritus between 460 and 370 BCE.
  - Possibly the idea originated with his teacher, Leucippus.
- Democritus thought of the world as being composed of very tiny "uncuttable" particles, which he called “atomoz.” Which is where we get the word atoms.
- These tiny, invisible particles were thought to be separated by voids -- empty space.
  - Democritus explained different substances were caused by differences in the sizes of the particles and the amount of empty space between them.
- This original Atomic Theory explained many properties of matter:
  - Solid, liquid, and gas states
    - State changes
  - Density
  - Mass
  - Hardness
  - Heterogenous Substances

Democritus

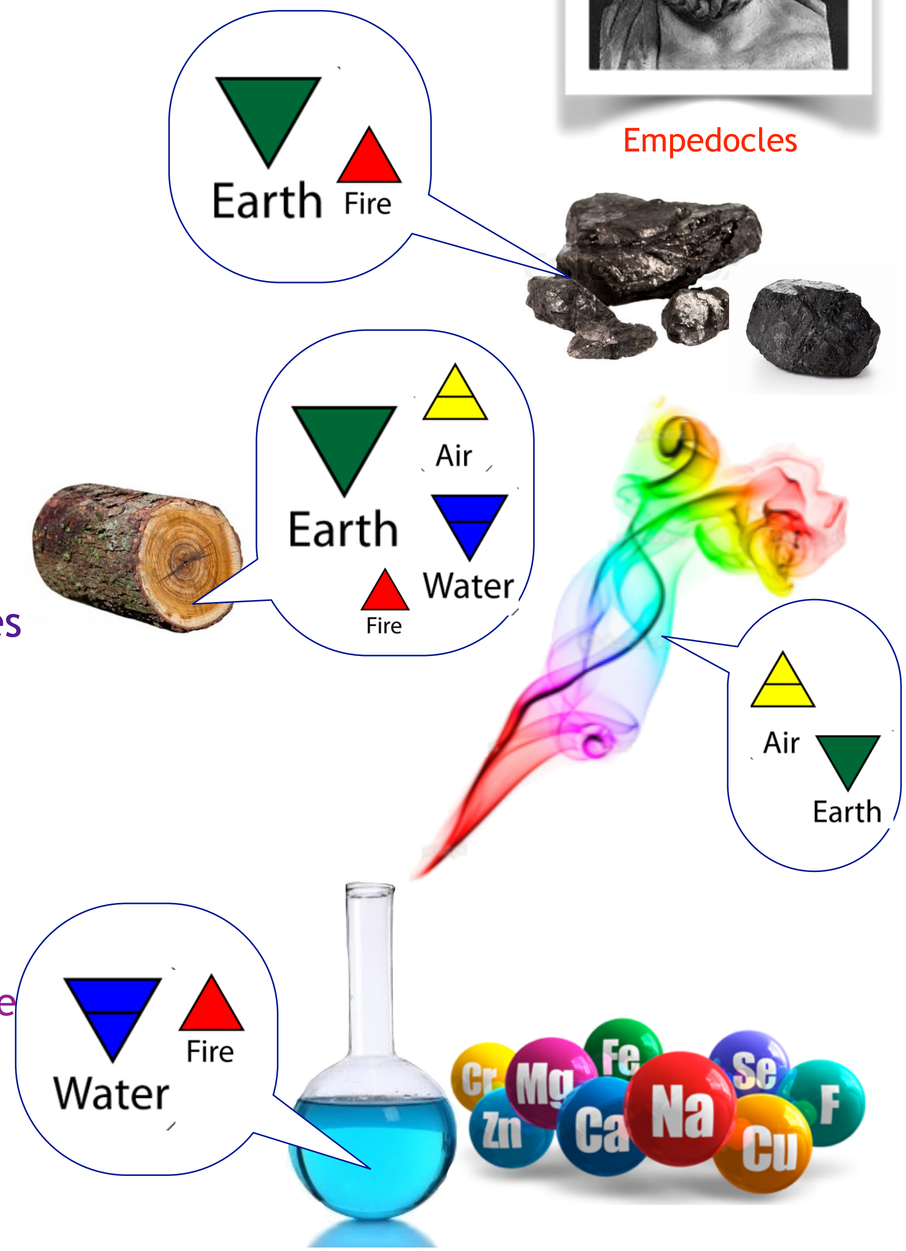


Elemental Theory



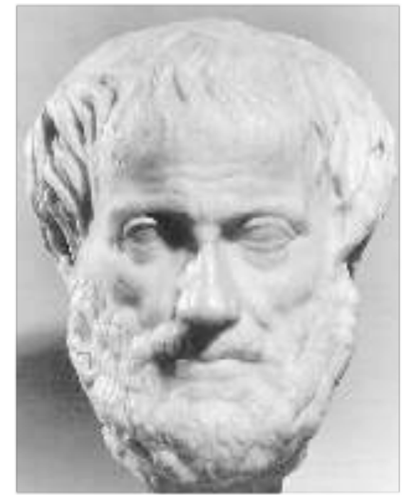
Empedocles

- Empedocles (490-430 B.C.) offered a different explanation.
- He suggested matter was made up of four basic substances:
  the elements **earth**, **air**, **fire**, and **water**.
- Elemental theory explained the differences in different types of matter as arising from the proportion, form, and qualities of the four basic elements that each contained.
- It explained states of matter. Liquids contained mostly water, solids contained mostly earth, gases were composed of mostly air.
- Experiments supported elemental theory.
  - Earth and fire came out of coal.
  - Smoke contained mostly air with some earth.
  - Steam contained mostly air with some water.
  - Alcohol was mostly water, but it's fire could be rele
  - Burning wood liberates ashes (earth), smoke (air), flames (fire) and water.

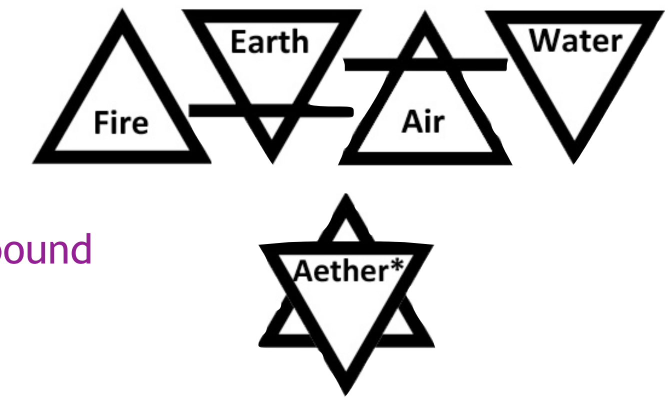


Tipping the Balance

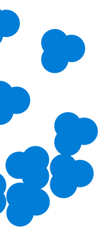
- Aristotle (384-322 B.C.) was the heir to Plato and teacher of Alexander the great.
- Plato, Aristotle's teacher argued everything could be understood by reason alone.
- Aristotle suggested otherwise.
  - He said the best way to come to know things was to start with observing and letting our observations guide our beliefs.
    - Aristotle believed the observations of Empedocles over the arguments of Democritus.
- Aristotle rejected the atomic theory of Democritus and advanced the elemental theory of Empedocles.
  - He added the idea that a fifth element must exist, Aether.
  - Aether he suggested was what existed between and what bound the other elements.
- Elemental theory became the dominant model that guided natural philosophy for the next 2000 years.



Aristotle 384-322 BCE



Atomic Theory



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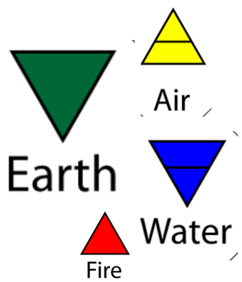

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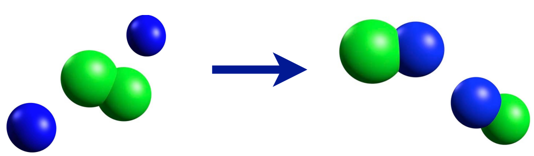

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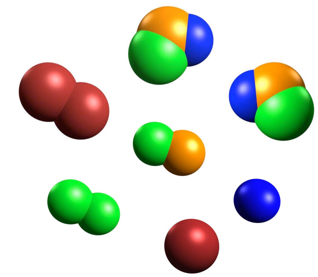

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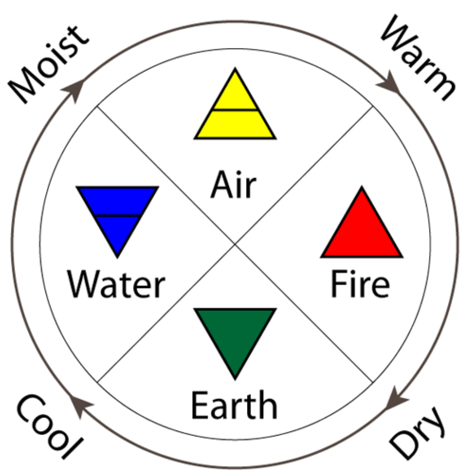
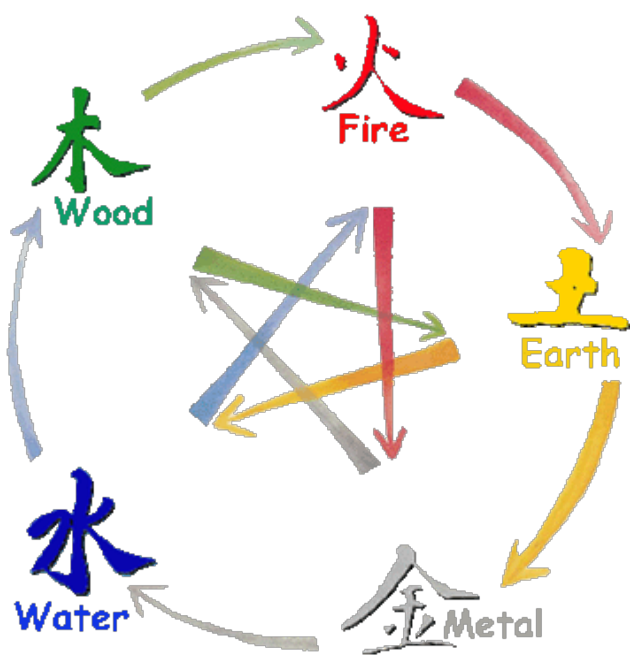
Discovering Elements

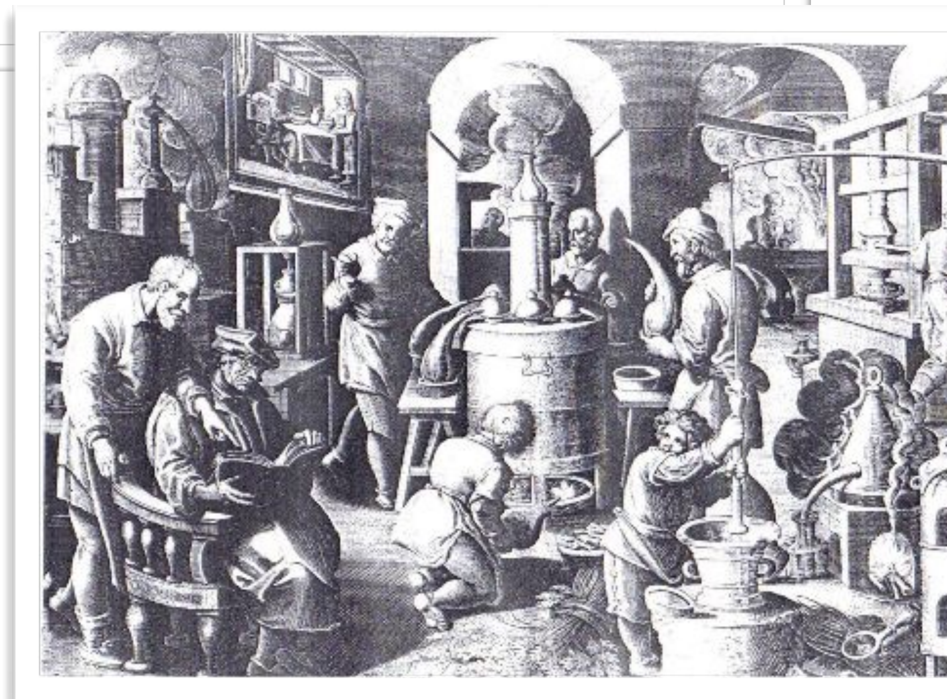
- For 2000 years alchemists around the world compiled observations of substances and their reactions.
- They purified mixtures and carefully cataloged the properties of each substance.
  - The physical properties that made each unique.
  - The chemical properties of their reactions.
- Trying to understand the composition and structure of matter sought the elements and tried to understand how they related to each other.

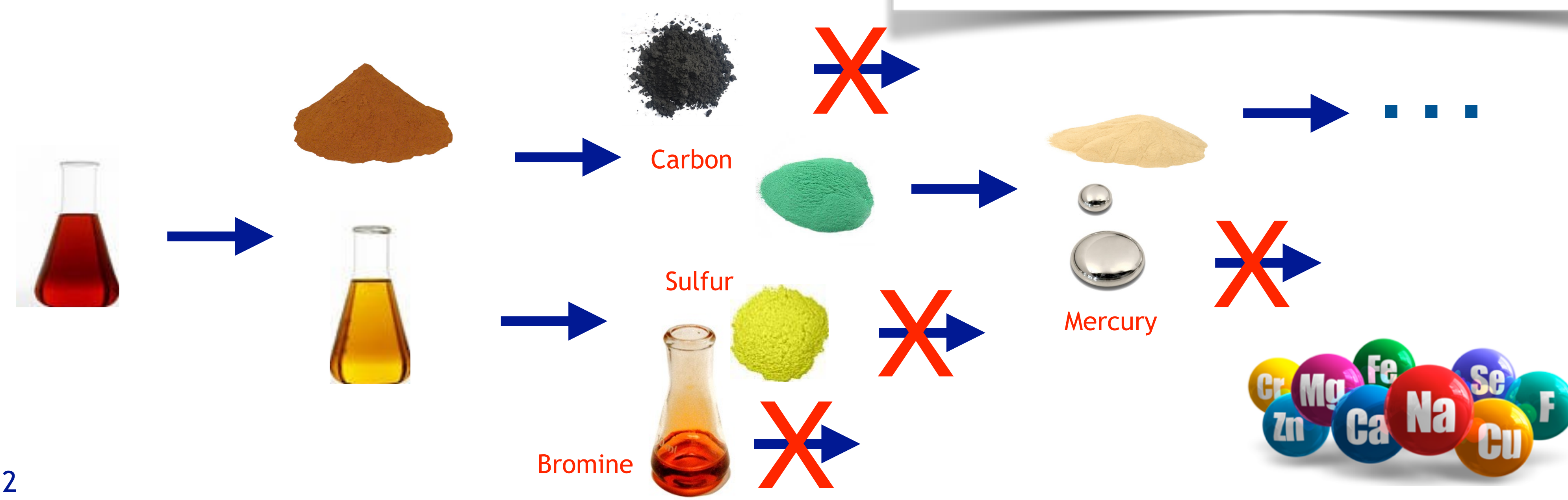




Discovering Elements

- Alchemists developed many of the techniques still used to separate mixtures into pure substances.
- Those substances were then decomposed by chemical reaction to try and discover their essential components.
  - Pure substances like salt, sulfur, niter, potash and aqua vitae were recombined to make powerful new mixtures and substances.
    - Mixtures like gun powder, wine, soap, lye, bronze, porcelain, and steel.



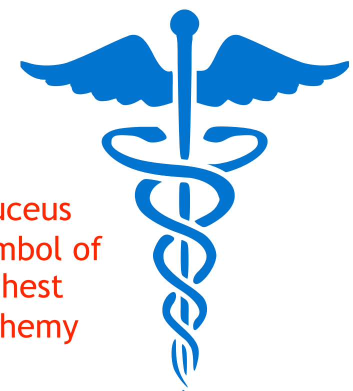


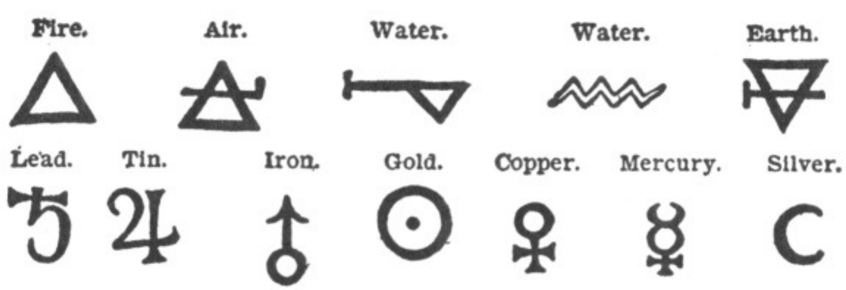
Discovering Elements

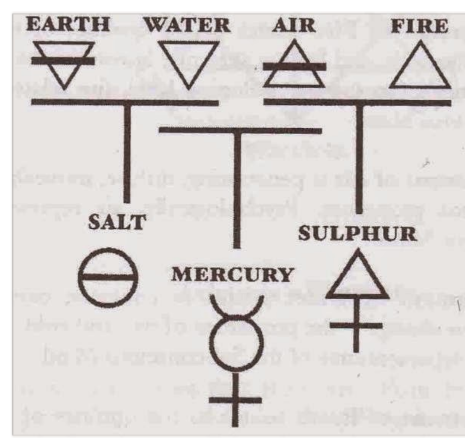
Paracelsus 1493-1541

- The substances that could not be broken down further were most prized and thought to be nearest to the greek elements alchemists sought.
- Renaissance alchemists like Paracelsus valued brimstone, quicksilver and salt as essential substances (essences).
  - Brimstone is now called sulfur
  - Quicksilver is now called mercury
- Alchemists recombined many of these substances to discover powerful properties used in healing.
  - Alchemists were the healers of their age.
  - The caduceus, the symbol of one of alchemies more powerful solvents and of alchemy itself eventually became the symbol of modern medicine.

Caduceus
the symbol of
Alkahest
& Alchemy







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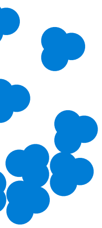

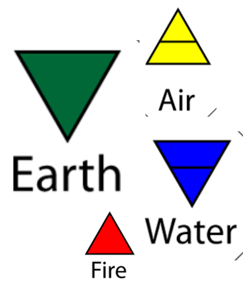

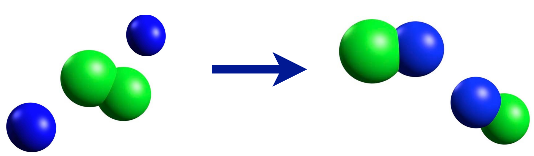

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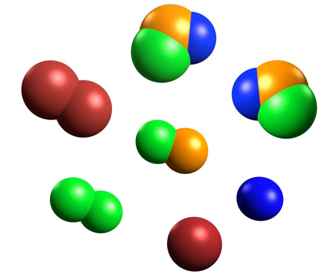

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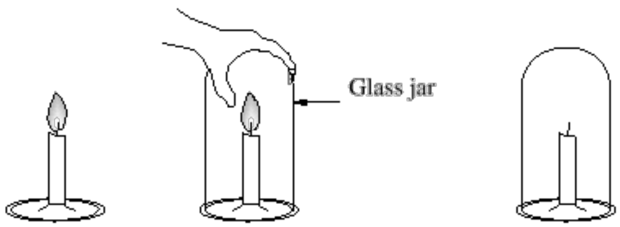
Looking for Fire

- By the 1600's we learned how to purify water, air was everywhere, we had discovered many rare earths… but fire was elusive.
- Fire seemed to come from stone or wood — but it couldn't be isolated and bottled like pure water, rare earth, or air.



Observations:

1. Some substances are flammable, others not.

   Organic plant or animal material (wood, paper, coal, oil, wax, fats, etc.) were flammable.

2. Once burned, these substances were converted to lighter materials (smoke, soot, ash).

3. A candle in a sealed container would burn, but then go out. And it could not be restarted.

   Unless you change the air in the sealed container.

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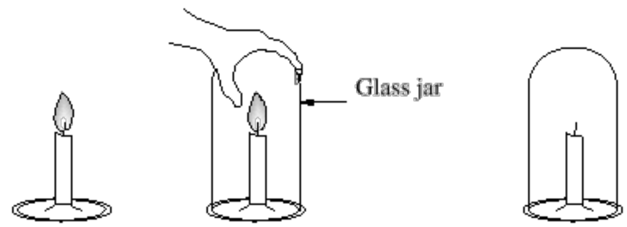


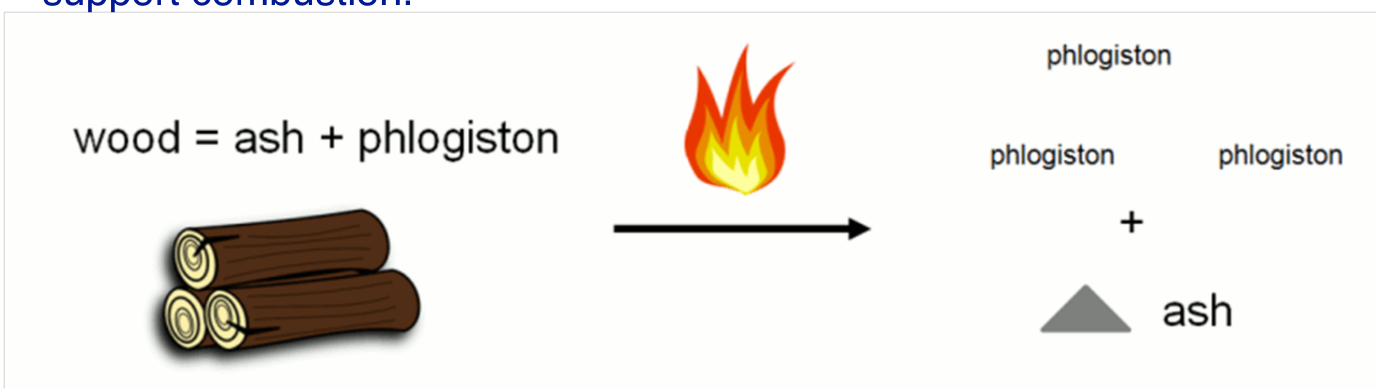
Hypothesis (explanations):

1. Some substances contain a fire like substance, others don't.

   Alchemists named this substance phlogiston.

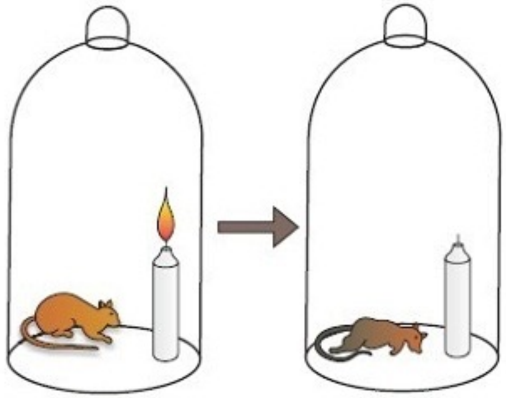
2. Phlogiston has mass and is released into the air.

3. Air can only hold so much phlogiston. Air that is fully phlogisticated cannot support combustion.



Looking for Fire

Experiments:



1. Place a mouse inside a sealed bell jar.

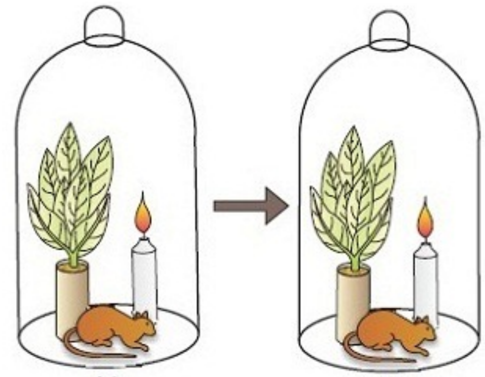
   Observation: the mouse dies.

   Hypothesis: Respiration is similar to combustion.

2. Placing a mouse inside the sealed container with the burning candle.

   Observation: the mouse and candle die faster.

   Hypothesis: Respiration and combustion release the same substance.



3. Placing a plant inside the sealed container with the mouse or the candle.

   Observe: the mouse and candle live longer.

   Hypothesis: Plants absorb the phlogiston.

   Hypothesis: Absorbing phlogiston is why organics burn.

4. After the candle burns out, put a plant in. After a while try to light the candle.

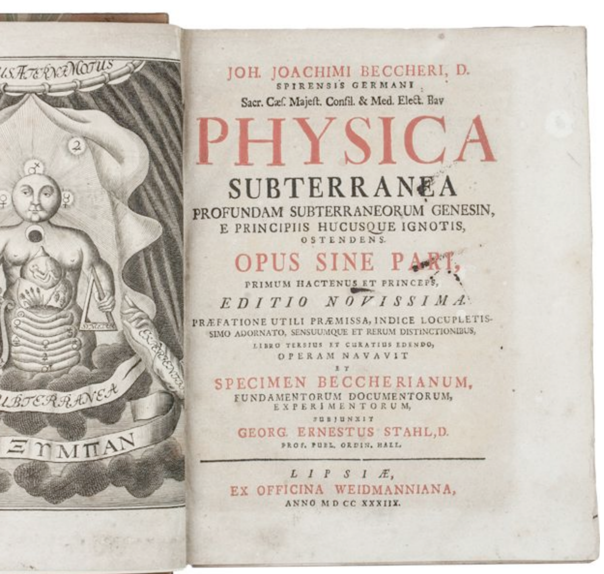
   Observe: the candle lights now.

   Hypothesis: The plant absorbed the phlogiston, allowing the air to support combustion again.

Looking for Fire

Johann J. Becher 1635-1682

- The phlogiston theory of combustion was offered in 1667 by the alchemist Johann Joachim Becher.
- The phlogiston theory suggested all combustion and respiration was based on release of a substance called phlogiston.
    - The phlogiston theory of combustion was faulty.
- But it was very useful. It was consistent with reality in many ways and guided us through many discoveries.
- That consistent model allowed us to effectively predict natural phenomena.
    - Using that theory we improved on bronze and refined steel
    - Using that theory we designed better forges, guns and canons.
    - Using that theory we improved on formulas for gun powder and we designed the first diving bell.
- Theories are never perfect.
- They don't need to be.
- The value of theory is being a good enough model of the truth, to guide our designs and predictions.
    - While we work on improving it.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PHYSICA
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PROFUNDAM SUBTERRANEORUM GENESIN,
E PRINCIPIIS HUCUSQUE IGNOTIS,
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OPERAM NAVAVIT
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EXPERIMENTORUM,
GEORG. ERNESTUS STAHL, D.
LIPSIÆ,
EX OFFICINA WEIDMANNIANA,
ANNO MDCC XXXIIX.

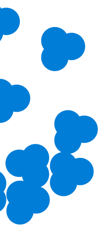
Scientific Method

- Consider the following pieces of the phlogiston puzzle.
- Decide if each is as an observation, theory, hypothesis, or experiment.

1. Some substances contain a fire like substance, others don't. — *Hypothesis*
2. A candle in a sealed container would burn, but then go out. And it could not be restarted. — *Observation*
3. Placing a mouse inside the sealed container with the burning candle. — *Experiment*
4. Plants absorb the phlogiston. — *Hypothesis*
5. Air that is fully phlogisticated cannot support combustion. — *Hypothesis*
6. After the candle burns out, put a plant in. After a while try to light the candle. — *Experiment*
7. The mouse and candle die faster in a smaller bell jar. — *Observation*
8. Organic material absorbs a substance called phlogiston, combustion is the release of phlogiston into air. — *Theory*

Ch02

Atomic Theory



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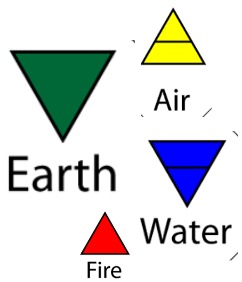

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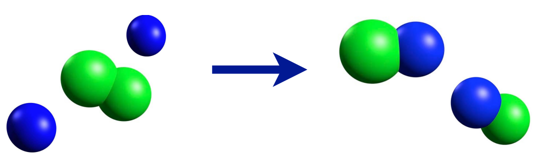

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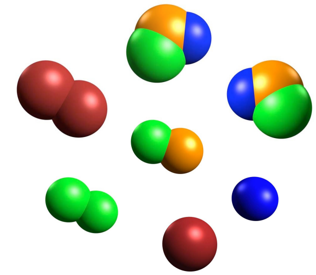

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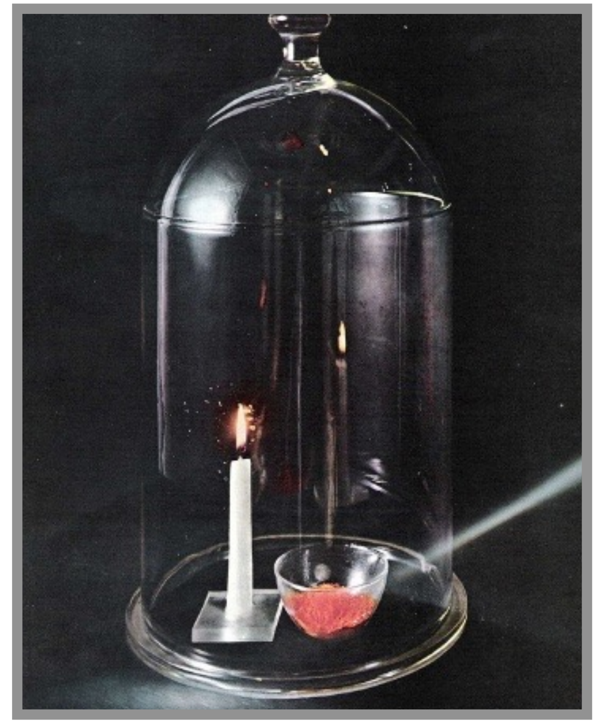
Discovering Oxygen

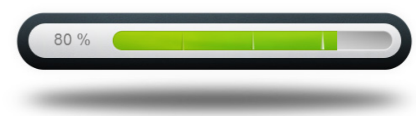
- Joseph Priestly was an English alchemist who immigrated to Pennsylvania in 1794.
- Ben Franklin asked Priestly to write the definitive book of that time on electricity.
- Priestly invented the rubber erase, seltzer water (he gave the rights to a neighbor named Schweppes)
- He discovered oxygen, firmly believed in the theory of Phlogiston, and conducted the experiment that disproved it’s existence.
- Priestly’s work lead to the end of elemental theory and asked the questions that brought us back to the idea of atoms.

Joseph Priestley 1733-1804

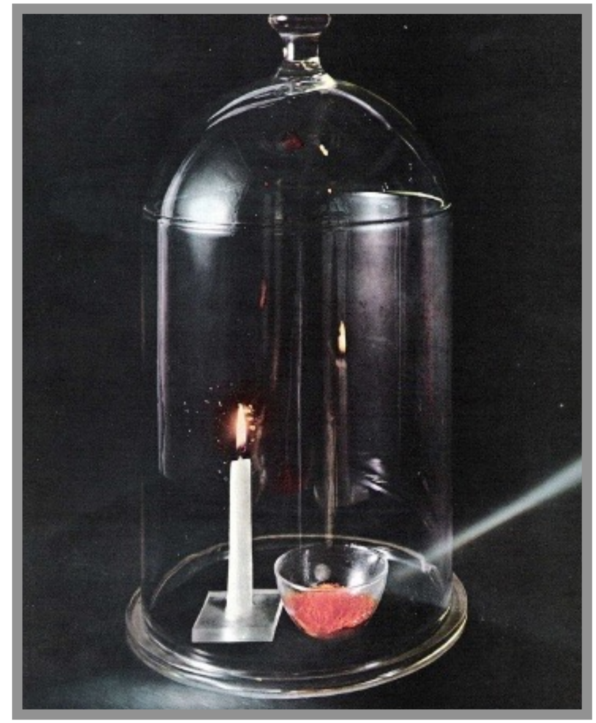
Discovering Oxygen

- Priestly attempted to produce “dephlogisticated air” by chemical synthesis. He succeeded.
- Priestly setup a bell jar with a burning candle in it.
  - In that jar he placed a substance we now know is mercuric oxide.
    - The candle went out and could not be lit again.
  - Using a lens and sunlight Priestly heated the mercuric oxide to trigger a chemical reaction.
    - He was able to relight the candle (using the same concentrated sunlight).
    - As long as the reaction continued, the candle burnt.
  - In subsequent experiments, he demonstrated that air could have it’s property of supporting combustion tuned.
    - He was able to make air that ranged from inert to almost five times as potent as the air man had believed was elemental.
  - In a series of experiments culminating in 1774, Priestley found that "air is not an elementary substance, but a composition," or mixture, of gases.
  - Among them was the colorless and highly reactive gas he called "dephlogisticated air.”





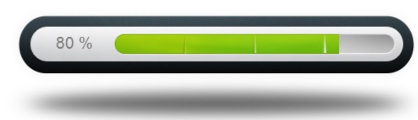
Discovering Oxygen



For 23 uninterrupted centuries humans has believed air, earth, fire and water were indestructible fundamental substances of which all matter was made.

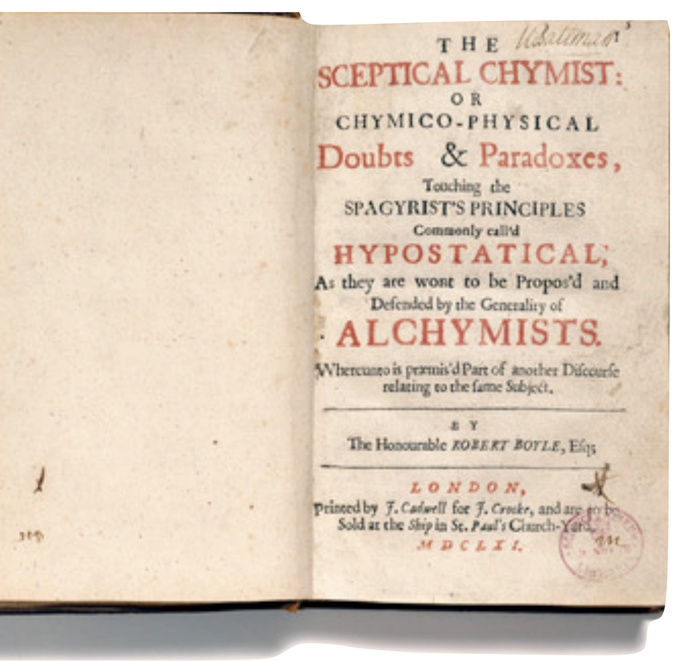
Priestly wrote that few concepts "have laid firmer hold upon the mind," than that air "is a simple elementary substance, indestructible and unalterable.”

Priestly’s demonstration that air was not an element left us with a very big hole in mankind picture of matter.



Empirical Scientific Method

Robert Boyle 1627-1691



THE
SCEPTICAL CHYMIST:
OR
CHYMICO-PHYSICAL
Doubts & Paradoxes,
Touching the
SPAGYRIST'S PRINCIPLES
Commonly call'd
HYPOSTATICAL;
As they are wont to be Propos'd and
Defended by the Generality of
ALCHYMISTS.
Whereunto is præmis'd Part of another Discourse
relating to the same Subject.

BY
The Honourable ROBERT BOYLE, Esq;

LONDON,
Printed by J. Cadwell for J. Crooke, and are to be
Sold at the Ship in St. Paul's Church-Yard.
MDCLXI.

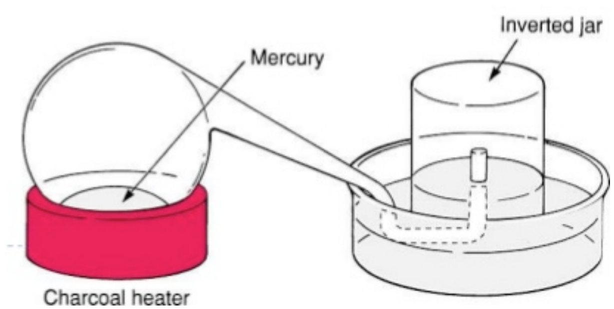
- Elemental theory was found to be inconsistent with the natural world.
- The observations shared and collected by alchemists for over 2000 years still offered truth.
- But the model by which we interpreted them failed us.
- A new explanation of matter was needed.

- The alchemist Robert Boyle had suggested we limit our study to the empirical.
- His treaty, the Skeptical Chymist was seen as a cornerstone book in the field of chemistry.
- Based on Boyle's ideas alchemists set aside mysticism, the ideas of spirits and essences… all but the empirical and what remained was the seed that became modern chemistry.
- Empirical method lead us to a new atomic theory.

Discovering Oxygen

- Antoine Lavoisier was a lawyer, politician, physicist, alchemist and the Commissioner of the Royal Gunpowder and Saltpeter Administration of France.
- He refined the formula for gun powder, made it a profitable industry for France, and helped establish the metric system.
- Antoine Lavoisier repeated Priestly's experiment.
- He observed mercuric oxide lost mass during the reaction.
  - Demonstrating that it wasn't pulling phlogiston out away from air, it was adding something to air.
- Lavoisier named that substance oxygen.
- He cataloged and carefully determined the properties of the 33 substances that (at that time) could not be decomposed chemically and named these the new elements.

Antoine Lavoisier 1743-1794

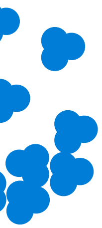


First Modern Elements

- Lavoisier redefined the term element to be any substance that could not be broken down by chemical reaction.
- He classified his 33 known elements into four groups:
  - Elastic fluids
    - Lavoisier included light, heat, oxygen, nitrogen, and hydrogen in this group.
  - Nonmetals
    - This group includes "oxidizable and acidifiable nonmetallic elements".
    - Lavoisier lists sulfur, phosphorus, carbon, hydrochloric acid, hydrofluoric acid, and boric acid.
  - Metals
    - These elements are "metallic, oxidizable, and capable of neutralizing an acid to form a salt."
    - They include antimony and arsenic (which are not considered metals today), silver, bismuth, cobalt, copper, tin, iron, manganese, mercury, molybdenum, nickel, gold, platinum, lead, tungsten, and zinc.
  - Earths
    - Lavoisier's salt-forming earthy solid "elements" included lime, magnesia (magnesium oxide), baryta (barium oxides), alumina (aluminum oxide), and silica (silicon dioxide).

	Noms nouveaux.	*Noms anciens correſpondans.*
Subſtances ſimples qui appartiennent aux trois règnes, & qu'on peut regarder comme les élémens des corps.	Lumière	Lumière.
	Calorique	Chaleur.
		Principe de la chaleur.
		Fluide igné.
		Feu.
		Matière du feu & de la chaleur.
	Oxygène	Air déphlogiſtiqué.
		Air empiréal.
		Air vital.
		Baſe de l'air vital.
	Azote	Gaz phlogiſtiqué.
		Mofète.
		Baſe de la mofète.
	Hydrogène	Gaz inflammable.
		Baſe du gaz inflammable.
Subſtances ſimples non métalliques oxidables & acidifiables.	Soufre	Soufre.
	Phoſphore	Phoſphore.
	Carbone	Charbon pur.
	Radical muriatique	Inconnu.
	Radical fluorique	Inconnu.
	Radical boracique	Inconnu.
Subſtances ſimples métalliques oxidables & acidifiables.	Antimoine	Antimoine.
	Argent	Argent.
	Arſenic	Arſenic.
	Biſmuth	Biſmuth.
	Cobalt	Cobalt.
	Cuivre	Cuivre.
	Etain	Etain.
	Fer	Fer.
	Manganèſe	Manganèſe.
	Mercure	Mercure.
	Molybdène	Molybdène.
	Nickel	Nickel.
	Or	Or.
	Platine	Platine.
	Plomb	Plomb.
	Tungſtène	Tungſtène.
	Zinc	Zinc.
Subſtances ſimples ſalifiables terreuſes.	Chaux	Terre calcaire, chaux.
	Magnéſie	Magnéſie, baſe du ſel d'epſom.
	Baryte	Barote, terre peſante.
	Alumine	Argile, terre de l'alun, baſe de l'alun.
	Silice	Terre ſiliceuſe, terre vitrifiable.

Atomic Theory



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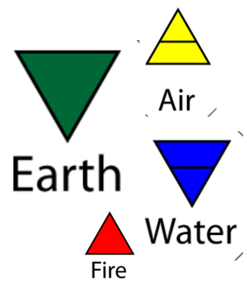
- The Greek Contribution
  - Atomic Theory 1.0
    - The idea of Atoms
  - Elemental Theory



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  - Laws of Stoichiometry
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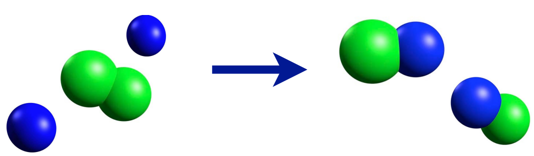
    - The Law of Constant Composition
    - The Law of Multiple Proportions



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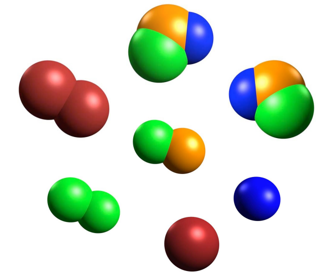

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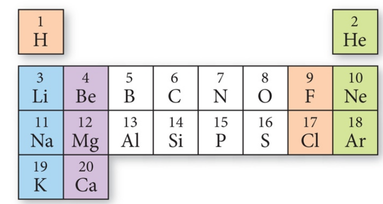


Law of Conservation of Mass

(also called Lavoisier's Law)

1

- In understanding the phlogiston experiments Lavoisier carefully determined the mass of each component of his reactions, both product and starting material.
- Combining his results with the observations of other alchemists, Lavoisier summarized a crucial observation about matter:

Observation

Antoine Lavoisier 1743-1794

The Law of Conservation of Mass:

In a chemical reaction, matter is neither created nor destroyed.

Law

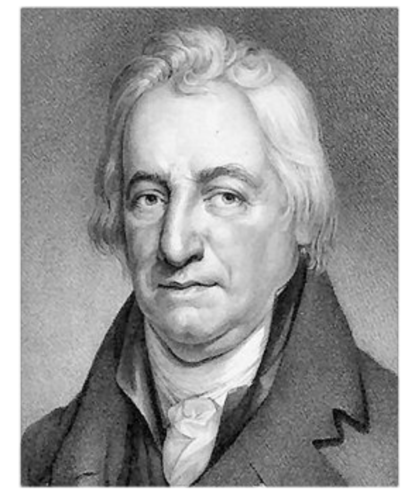
Observation

eg. 9.3g of iron reacts with 10.7g sulfur to form 20.0g iron pyrite.
eg. 20.0g of water breaks down to form 17.8g oxygen and 2.2g hydrogen.

Law of Constant Composition

(also called the Law of Definite Proportions or Proust's Law)

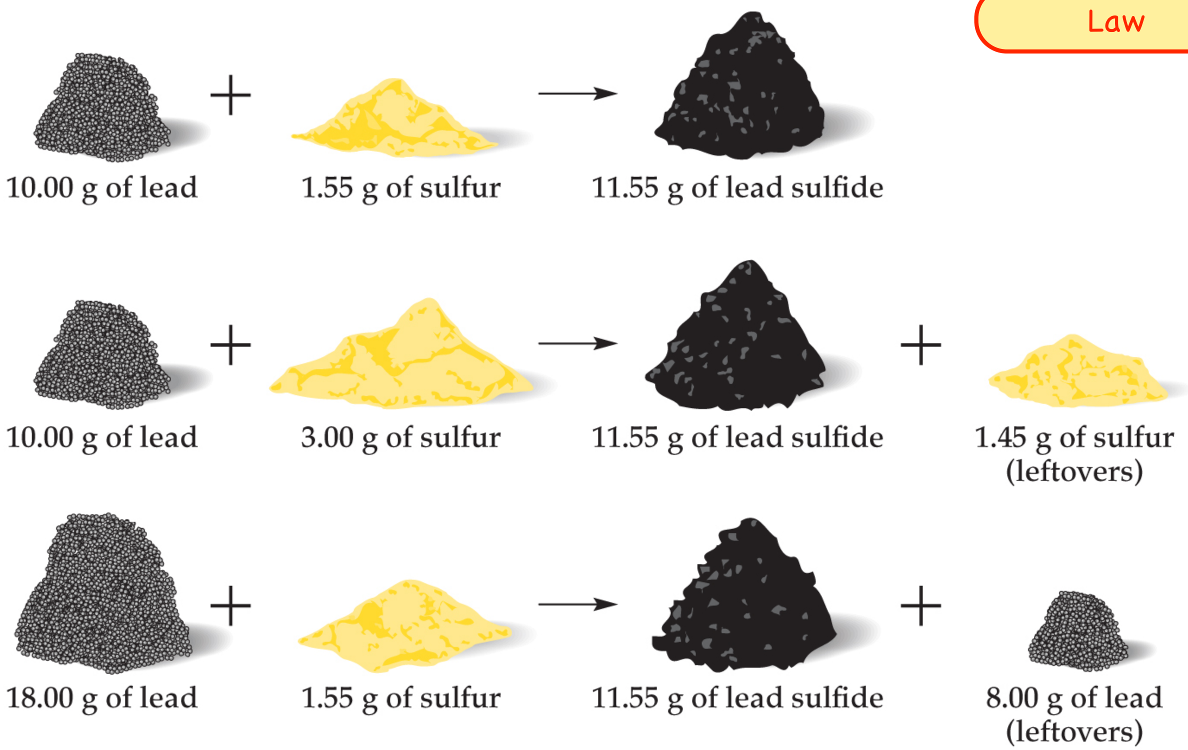
2



Joseph Proust 1754-1826

All samples of a given compound have the same proportion of their constituent elements.

Law

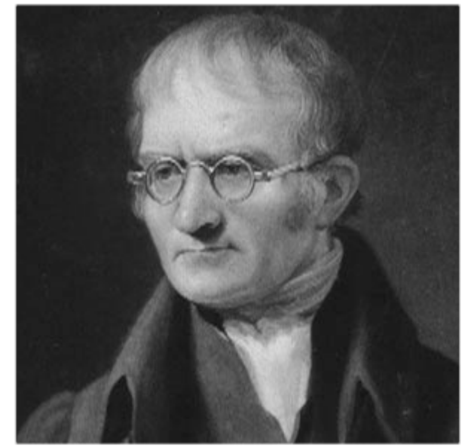


Observation

Water is <u>always</u> 88.8% by weight oxygen, 11.2% hydrogen.
Table salt is <u>always</u> 39.3% by weight sodium, 60.7% chloride.

John Dalton

- John Dalton, and English school teacher explored different substances that decomposed to the same elements.
  - Using Lavoisier's definition of an element.
- He observed a pattern in the ratio of elements produced from the these different substances.
- The ratio was always a simple whole number.



John Dalton 1766-1844

Compound	Mass of Nitrogen	Mass of Oxygen
N_2O	1.00 grams	0.571 grams
NO	1.00 grams	1.14 grams
NO_2	1.00 grams	2.28 grams
NO_4	1.00 grams	4.57 grams

Ratio of Compounds	Ratio of Masses	Ratio	Ratio Small Number
$NO_4:NO_2$	4.57:2.28	2:1	2
$NO_4:NO$	4.57:1.14	4:1	4
$NO_4:N_2O$	4.57:0.571	8:1	8
$NO_2:NO$	2.28:1.14	2:1	2
$NO_2:N_2O$	2.28:0.571	4:1	4
$NO:N_2O$	1.14:0.571	2:1	2
$NO_4:NO_2:NO:N_2O$	4.57:2.28:1.14:0.571	8:4:2:1	1

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$NO_4:NO_2:NO:N_2O$	4.57:2.28:1.14:0.571	8:4:2:1	1

Law of Multiple Proportions

3

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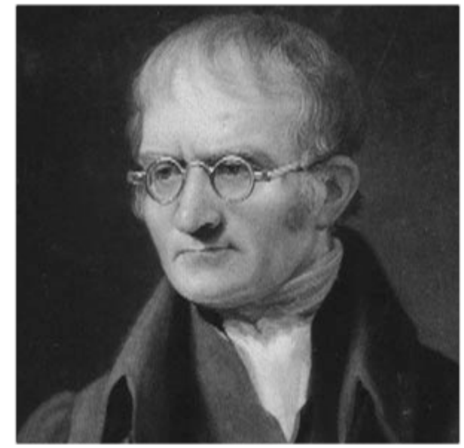
Law



John Dalton 1766-1844

When two elements (call them A and B) form two different compounds, masses of element B that combine with 1g of element A can always be expressed as a ratio of small whole numbers.

Observation

Ratio of Compounds	Ratio of Masses	Ratio	Ratio Small Number
$NO_4:NO_2$	4.57:2.28	2:1	2
$NO_4:NO$	4.57:1.14	4:1	4
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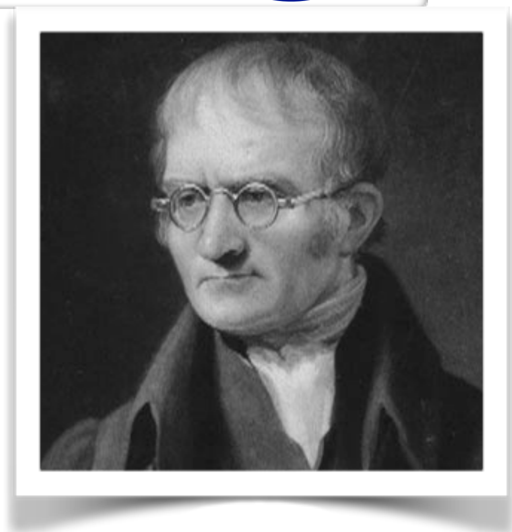
$NO_4:NO_2:NO:N_2O$	4.57:2.28:1.14:0.571	8:4:2:1	1

Law of Multiple Proportions

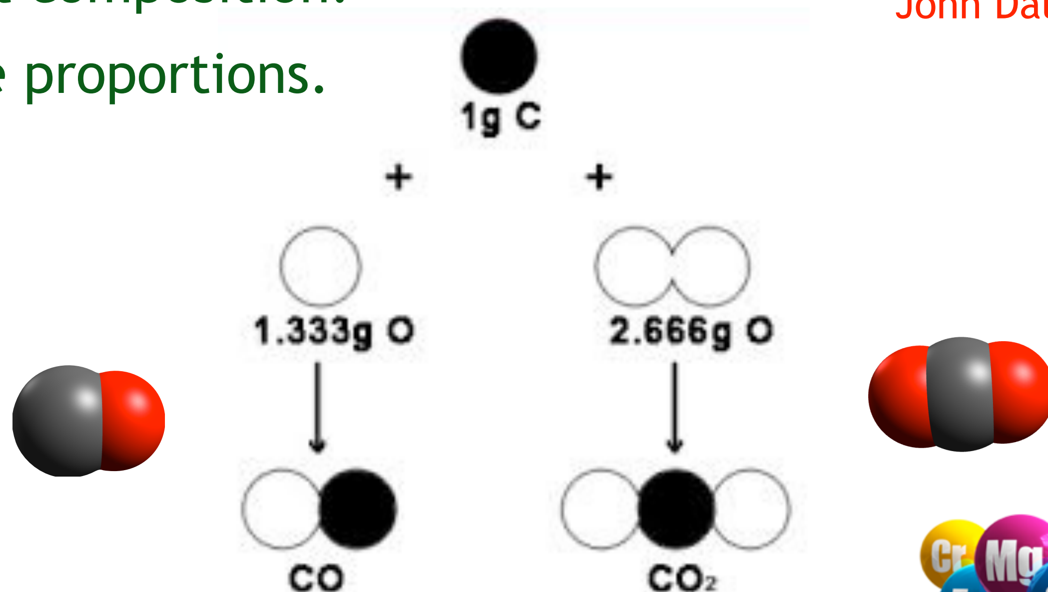
3

- John Dalton explained the law of multiple proportions, by suggesting Democritus may have been right in his atomic theory.
- That if matter did exist as small discreet packets, atoms, it would explain all three of these laws.



John Dalton 1766-1844

1. The law of conservation of mass.
2. The law of constant composition.
3. The law of multiple proportions.



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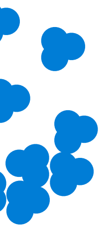

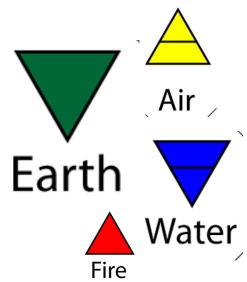

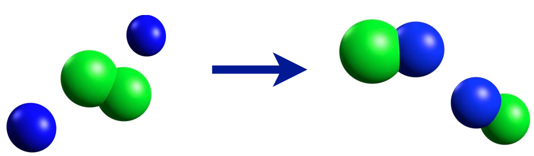

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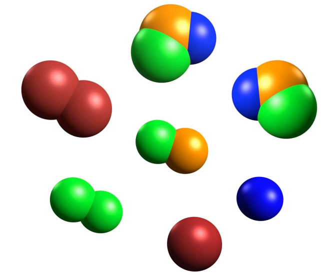
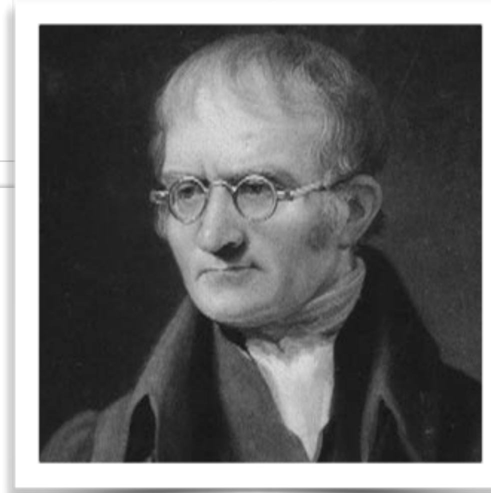


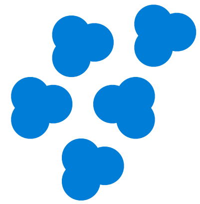
1 H							2 He
3 Li	4 Be	5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg	13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca						

Atomic Theory 2.0



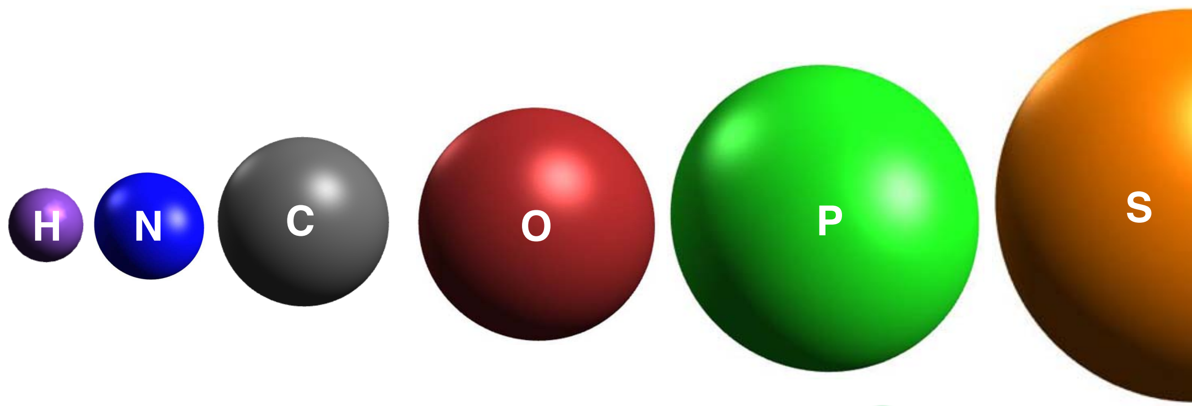
John Dalton 1766-1844

- To explain the Laws of Stoichiometry John Dalton Proposed a new Atomic Theory refined with four postulates.
    - "Elements are composed of minute particles called atoms." Dalton reintroduced the atom to the world.
    - "Atoms of the same element are alike in mass and size. Atoms of different elements have different masses and sizes." Dalton suggested that atoms come in different flavors, corresponding to the different elements.

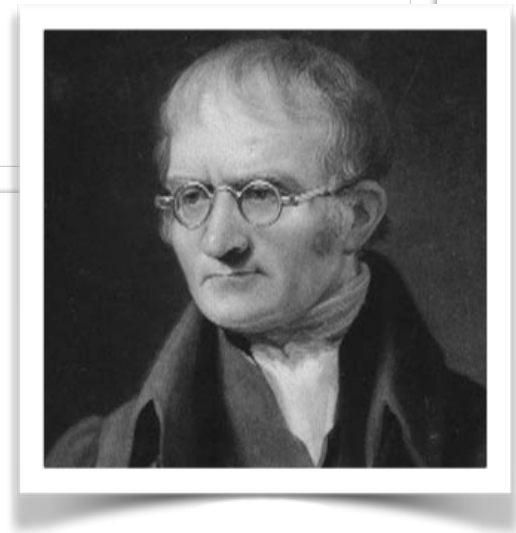


ELEMENTS

	Wt.		Wt.
Hydrogen	1	Copper	56
Azote	5	Lead	90
Carbon	6	Silver	190
Oxygen	7	Gold	190
Phosphorus	9	Platina	190
Sulfur	13	Mercury	167

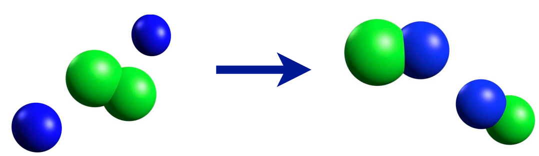


Atomic Theory 2.0

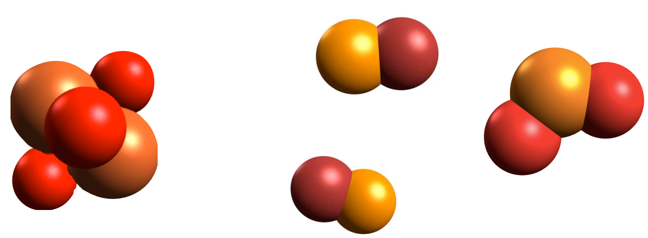


John Dalton 1766-1844

- To explain the Laws of Stoichiometry John Dalton Proposed a new Atomic Theory refined with four postulates.
  - “The atoms of one element cannot be changed into atoms of a different element by chemical reaction; atoms are neither created nor destroyed in chemical reactions.”
    Dalton said that atoms are an indivisible and unchanging component (in chemical reactions).



  - “Compounds are formed when atoms of more than one element combine; a given compound always has the same relative number and kind of atoms.” The idea that atoms define substances.



Ch02

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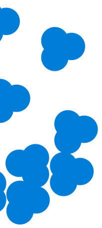

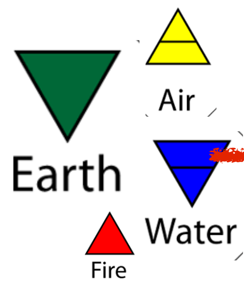

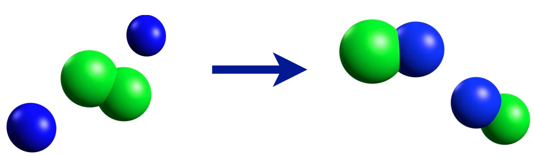

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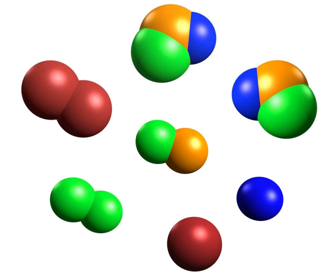

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Organizing the Elements

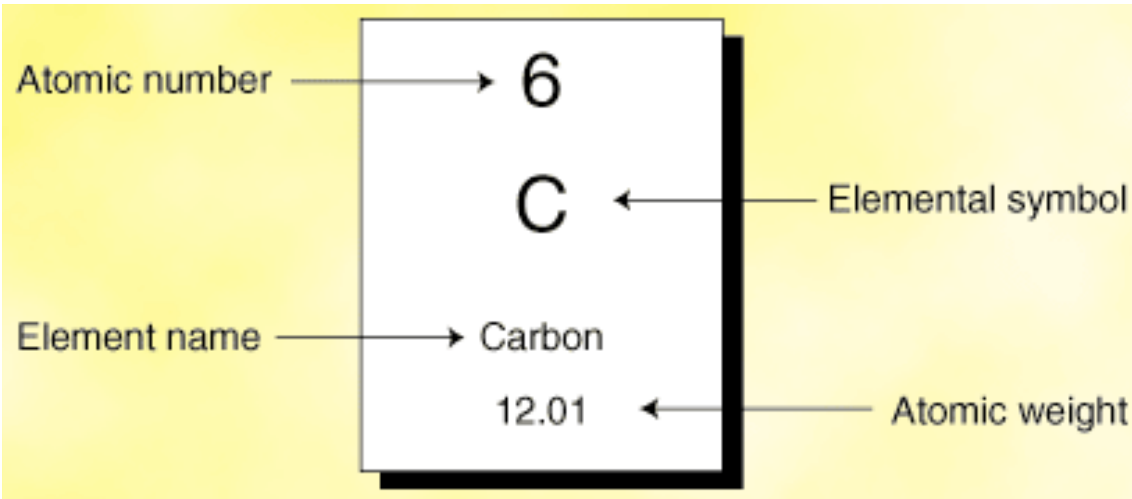
- Finding new pure substances with useful and interesting properties made chemistry a valuable science.
- As chemists sought out more pure substances and documented their properties they explored how those substances could be made or decomposed.
- They quickly realized that every substance they discovered could be decomposed into one of a handful of unique substances that could not themselves be decomposed.
- The called those hand full of cornerstone substances elements.
- Between the early 1700's and mid 1800's chemists sought out and found over 50 of those those essential substances.
- At we found more and more elements we needed to organize them.
- So we started by making flash cards.
- We gave each element a symbol.

For the next exam:
Know the name and symbol of the first 18 elements.

Symbols for 18 Elements

Hydrogen (H)
Helium (He)
Lithium (Li)
Beryllium (Be)
Boron (B)
Carbon (C)
Nitrogen (N)
Oxygen (O)
Fluorine (F)
Neon (Ne)
Sodium (Na)
(latin: **Na**trium)
Mgagnesium (Mg)
Aluminum (Al)
Silicon (Si)
Phosphorus (P)
Sulfur (S)
Clhlorine (Cl)
Argon (Ar)

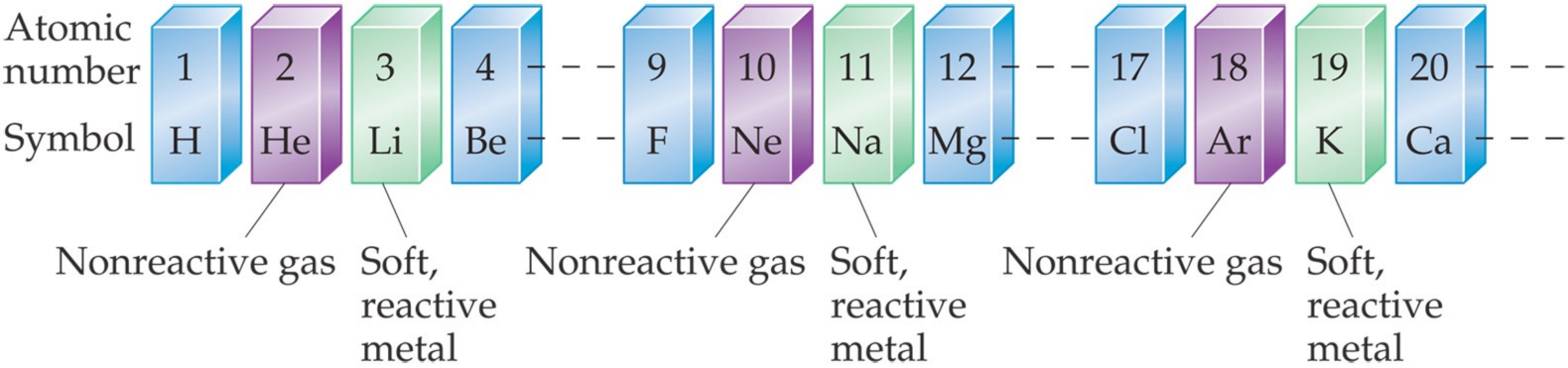
Organizing the Elements



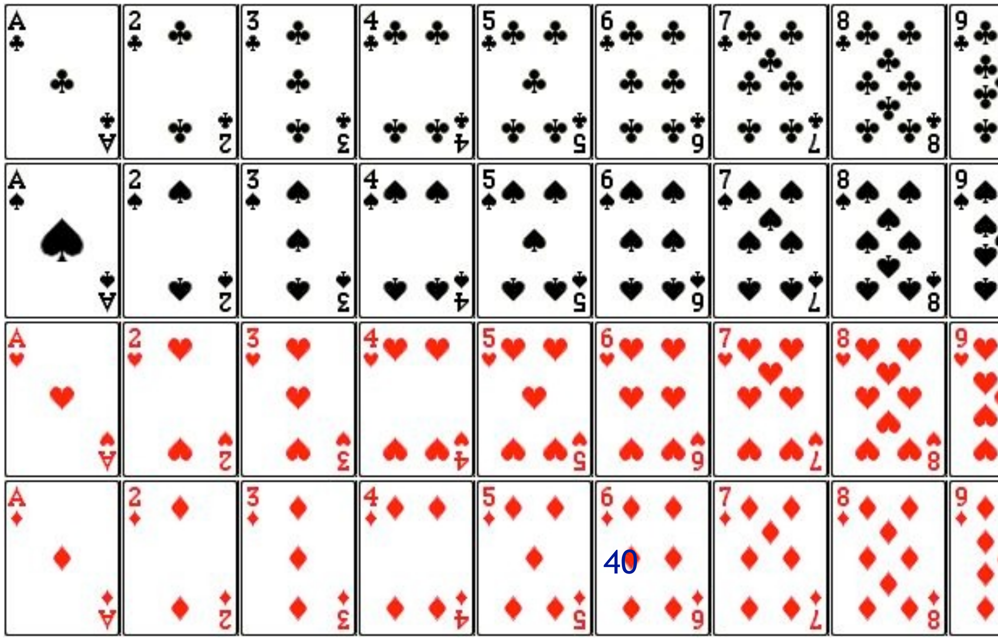
Symbols have 1, 2 or 3 letters. If 1 letter is used, it is capitalized. If 2 or 3 letters are used, only the first is capitalized.

- We started by making flash cards.
- We gave each element a symbol.
- Then we lined them up by increasing weight, just like you might organize a poker hand.
- We gave each element a serial number (atomic number), to indicate it's place in the sequence of increasing weight.

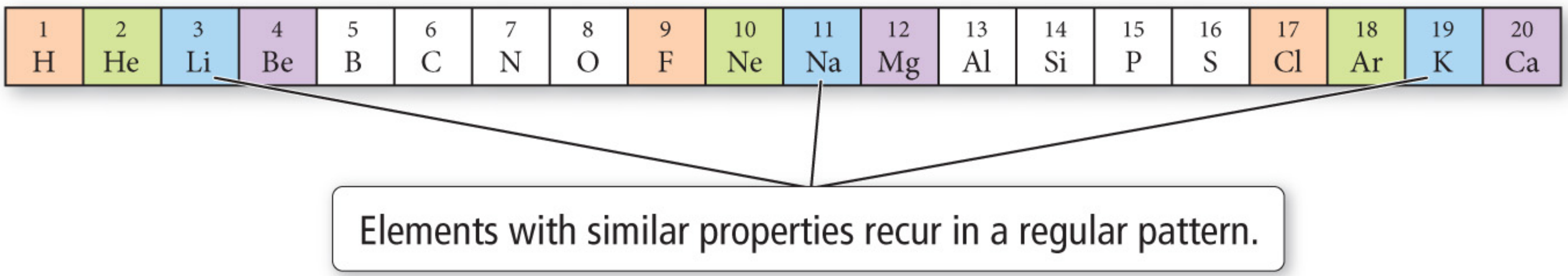
Periodicity



- We lined up all the cards by weight. From lightest to heaviest.
- Then we looked at their chemical and physical properties and saw a repeating pattern.
- Periodically, the same property shows up again and again and again.
- So instead of making it one really lone line, we wrapped our set of cards so that those periodic trends lined up.



Periodicity



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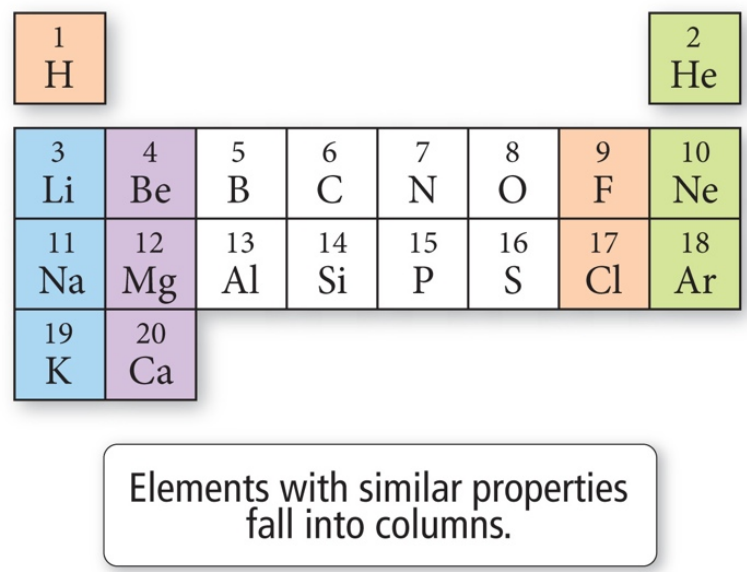
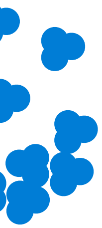
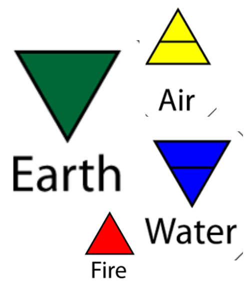


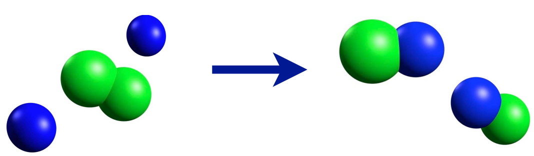
Atomic Theory



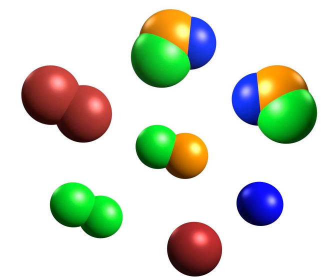
- Scientific Method
  - The iterative nature of theory.
- The Greek Contribution
  - Atomic Theory 1.0
    - The idea of Atoms
  - Elemental Theory



- Alchemy, Discovering Elements
  - Salt, Sulfur, and Mercury
  - The theory of Phlogiston
  - Discovery of Oxygen
  - Laws of Stoichiometry
    - The Law of Conservation of Mass
    - The Law of Constant Composition
    - The Law of Multiple Proportions



- Renaissance of the Atom
  - Atomic Theory 2.0
    - explaining compounds
    - the mole & molar mass

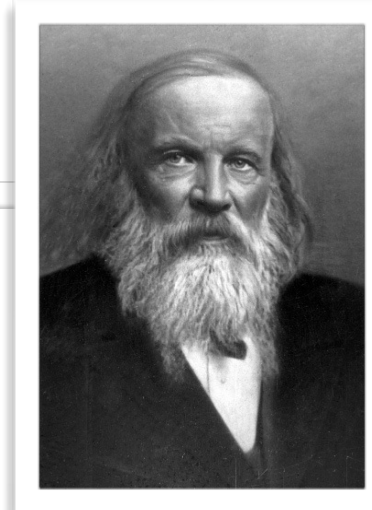


- Mendeleev, the Periodic Table
  - Periodicity
    - Patterns of elements
  - The Periodic Table
    - Metals & Non-metals
    - Representative Elements
    - Periods, Groups & Families
  - Class Periodic Table

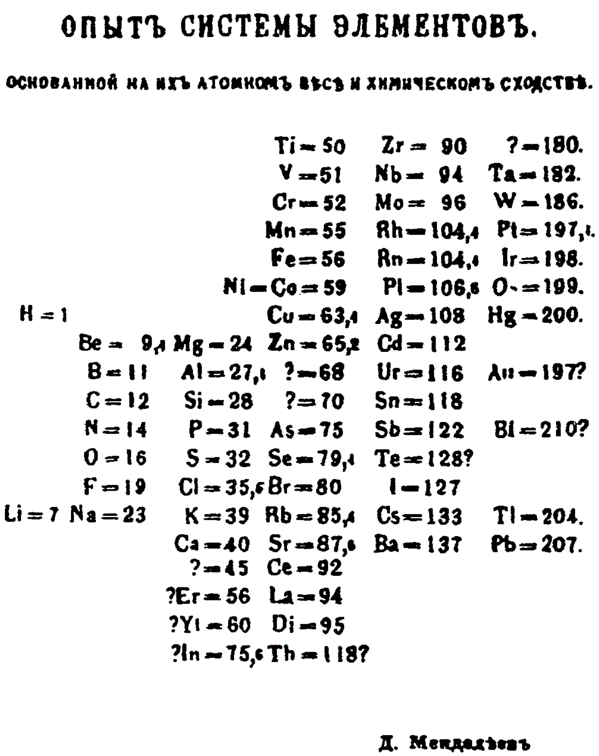
1 H							2 He
3 Li	4 Be	5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg	13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca						

Periodic Table

- Dmitri Ivanovich Mendeleev, a Russian chemistry teacher, is credited for producing the first periodic table in 1871.
- There were about 50 elements in his first table.
- Periodic law predicted elements that weren't yet know, so Medeleev left holes in his periodic table — to leave room for when they were discovered.



Dmitri Mendeleev
1834-1907



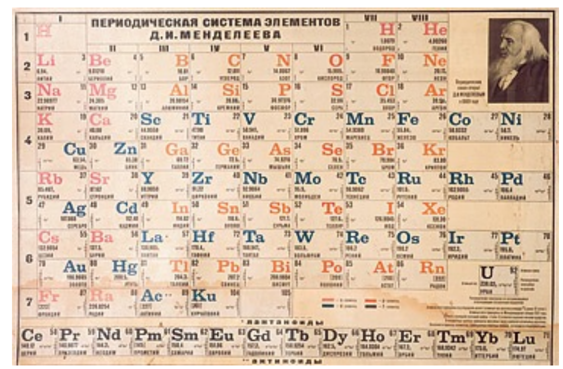
ОПЫТЪ СИСТЕМЫ ЭЛЕМЕНТОВЪ.

ОСНОВАННОЙ НА ИХЪ АТОМНОМЪ ВѢСѢ И ХИМИЧЕСКОМЪ СХОДСТВѢ.

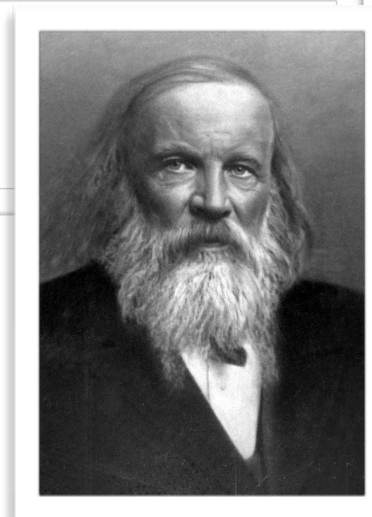
Ti=50 Zr=90 ?=180.
V=51 Nb=94 Ta=182.
Cr=52 Mo=96 W=186.
Mn=55 Rh=104,4 Pt=197,4.
Fe=56 Rn=104,4 Ir=198.
Ni=Co=59 Pl=106,6 Os=199.
H=1 Cu=63,4 Ag=108 Hg=200.
Be=9,4 Mg=24 Zn=65,2 Cd=112
B=11 Al=27,4 ?=68 Ur=116 Au=197?
C=12 Si=28 ?=70 Sn=118
N=14 P=31 As=75 Sb=122 Bi=210?
O=16 S=32 Se=79,4 Te=128?
F=19 Cl=35,5 Br=80 I=127
Li=7 Na=23 K=39 Rb=85,4 Cs=133 Tl=204.
Ca=40 Sr=87,6 Ba=137 Pb=207.
?=45 Ce=92
?Er=56 La=94
?Yt=60 Di=95
?In=75,6 Th=118?

Д. Менделѣевъ

I	II	III	IV	V	VI	VII	VIII		
H 1.01									
Li 6.94	Be 9.01	B 10.8	C 12.0	N 14.0	O 16.0	F 19.0			
Na 23.0	Mg 24.3	Al 27.0	Si 28.1	P 31.0	S 32.1	Cl 35.5			
K 39.1	Ca 40.1		Ti 47.9	V 50.9	Cr 52.0	Mn 54.9	Fe 55.9	Co 58.9	Ni 58.7
Cu 63.5	Zn 65.4			As 74.9	Se 79.0	Br 79.9			
Rb 85.5	Sr 87.6	Y 88.9	Zr 91.2	Nb 92.9	Mo 95.9		Ru 101	Rh 103	Pd 106
Ag 108	Cd 112	In 115	Sn 119	Sb 122	Te 128	I 127			
Ce 133	Ba 137	La 139		Ta 181	W 184		Os 194	Ir 192	Pt 195
Au 197	Hg 201	Tl 204	Pb 207	Bi 209					
			Th 232		U 238				



Elements Mendeleev Predicted



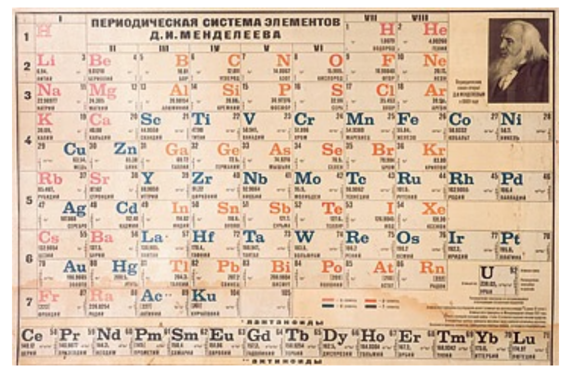
Dmitri Mendeleev
1834-1907

Mendeleev's Predicitons

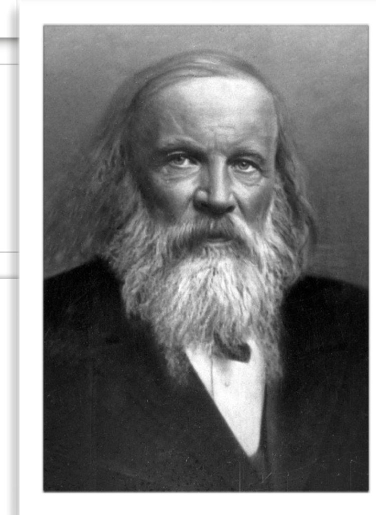
Property	Ekaaluminium	Gallium
atomic mass	68	69.72
density (g/cm3)	6.0	5.904
melting point (°C)	Low	29.78
oxide's formula	Ea2O3 (density: 5.5 g/cm3) (soluble in both alkalis and acids)	Ga2O3 (density: 5.88 g/cm3) (soluble in both alkalis and acids)
chloride's formula	Ea2Cl6 (volatile)	Ga2Cl6 (volatile)

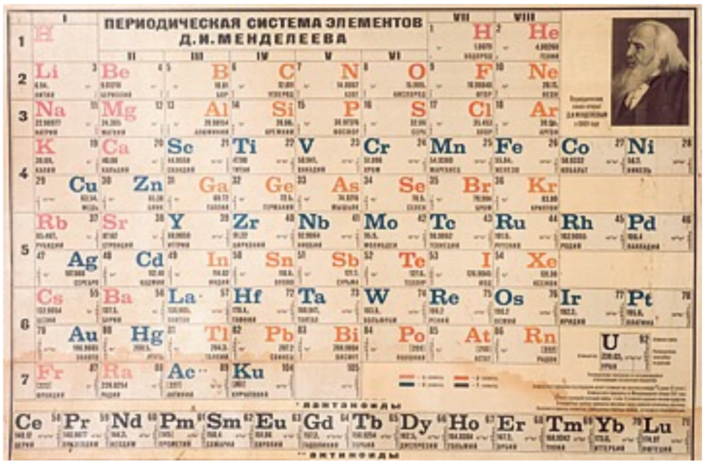
And also…

Property	Ekasilicon	Germanium
atomic mass	72	72.61
density (g/cm3)	5.5	5.35
melting point (°C)	high	947
color	grey	grey
oxide type	refractory dioxide	refractory dioxide
oxide density (g/cm3)	4.7	4.7
oxide activity	feebly basic	feebly basic
chloride boiling point	under 100 °C	86 °C (GeCl4)
chloride density (g/cm3)	1.9	1.9

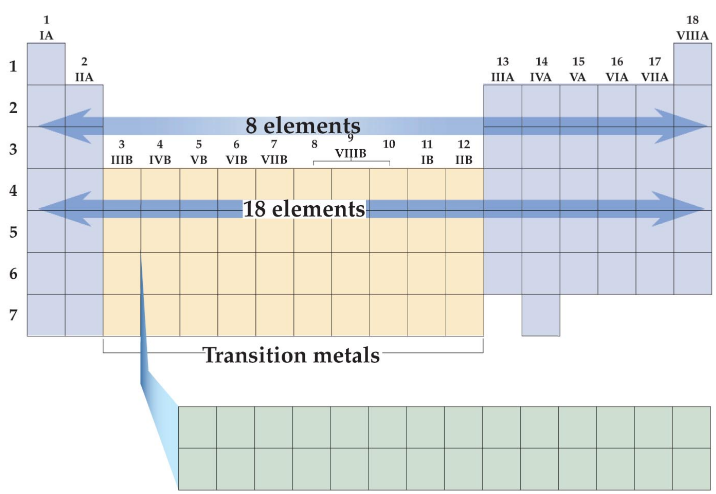


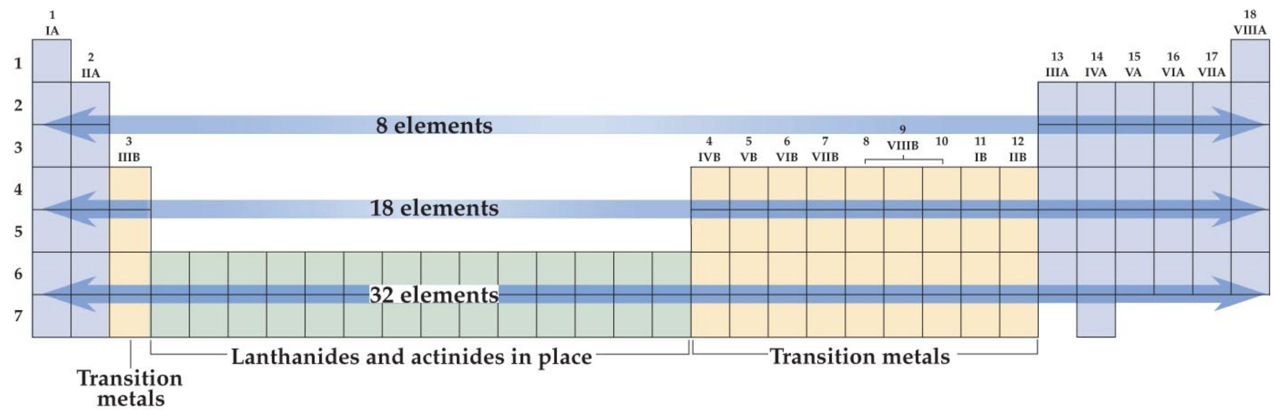
Periodic Table





- As we added more elements the table grew.
- To make it more manageable, we cut out the lanthanide and actinide cards and set them in a separate table.





The 118 Known Elements

The last 3 were officially added 12-30-2015

Periodic Table of the Elements

Atomic Number
Symbol
Name
Atomic Mass

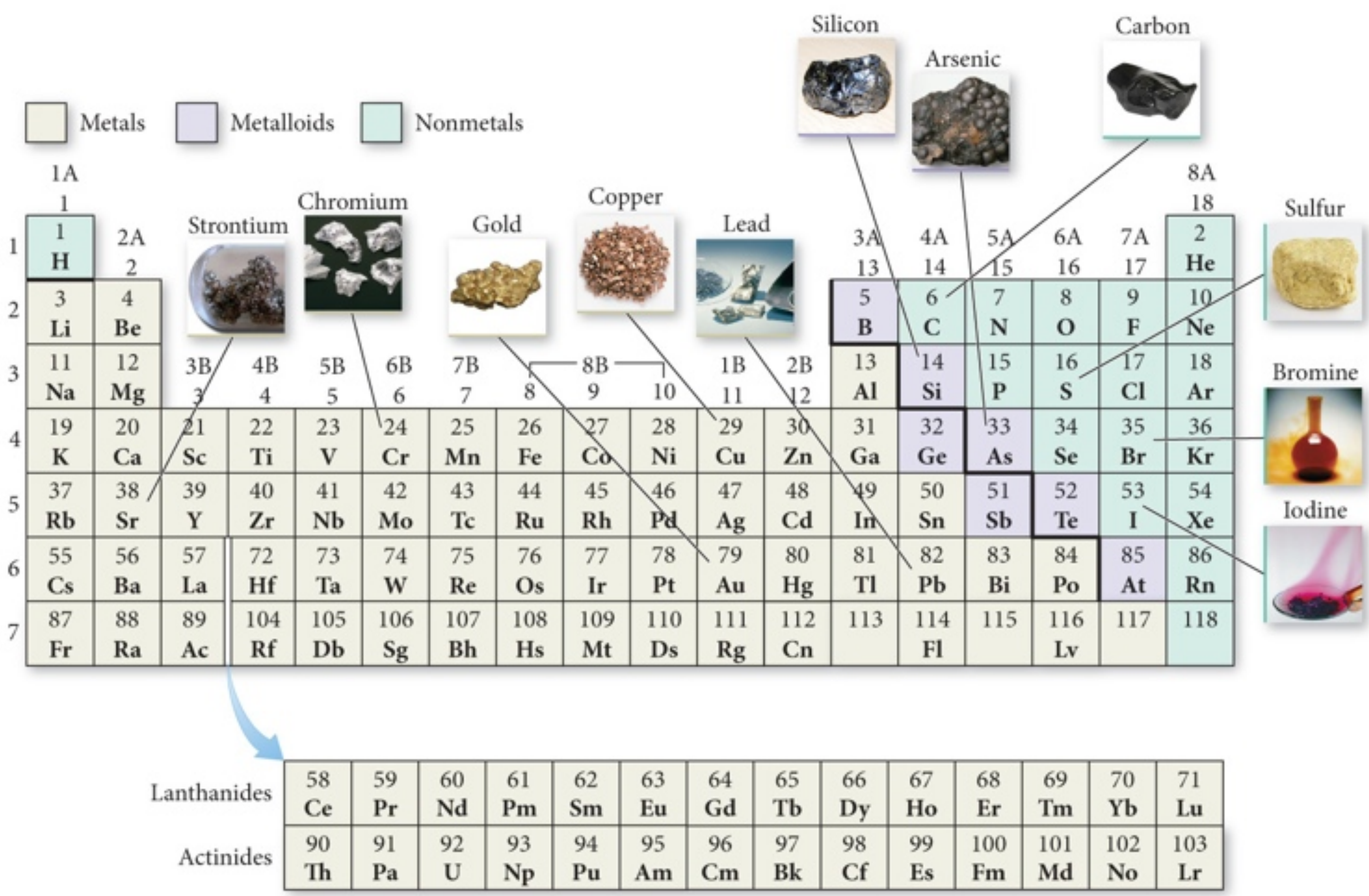
1 IA	2 IIA 2A	3 IIIB 3B	4 IVB 4B	5 VB 5B	6 VIB 6B	7 VIIB 7B	8	9 VIII	10	11 IB 1B	12 IIB 2B	13 IIIA 3A	14 IVA 4A	15 VA 5A	16 VIA 6A	17 VIIA 7A	18 VIIIA 8A
1 H Hydrogen 1.008																	2 He Helium 4.003
3 Li Lithium 6.941	4 Be Beryllium 9.012											5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.998	10 Ne Neon 20.180
11 Na Sodium 22.990	12 Mg Magnesium 24.305											13 Al Aluminum 26.982	14 Si Silicon 28.086	15 P Phosphorus 30.974	16 S Sulfur 32.066	17 Cl Chlorine 35.453	18 Ar Argon 39.948
19 K Potassium 39.098	20 Ca Calcium 40.078	21 Sc Scandium 44.956	22 Ti Titanium 47.88	23 V Vanadium 50.942	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.933	27 Co Cobalt 58.933	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.39	31 Ga Gallium 69.732	32 Ge Germanium 72.61	33 As Arsenic 74.922	34 Se Selenium 78.09	35 Br Bromine 79.904	36 Kr Krypton 84.80
37 Rb Rubidium 84.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.94	43 Tc Technetium 98.907	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.906	46 Pd Palladium 106.42	47 Ag Silver 107.868	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 126.904	54 Xe Xenon 131.29
55 Cs Cesium 132.905	56 Ba Barium 137.327	57-71	72 Hf Hafnium 178.49	73 Ta Tantalum 180.948	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 196.967	80 Hg Mercury 200.59	81 Tl Thallium 204.383	82 Pb Lead 207.2	83 Bi Bismuth 208.980	84 Po Polonium [208.982]	85 At Astatine 209.987	86 Rn Radon 222.018
87 Fr Francium 223.020	88 Ra Radium 226.025	89-103	104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Seaborgium [266]	107 Bh Bohrium [264]	108 Hs Hassium [269]	109 Mt Meitnerium [268]	110 Ds Darmstadtium [269]	111 Rg Roentgenium [272]	112 Cn Copernicium [277]	113 Uut Ununtrium unknown	114 Fl Flerovium [289]		116 Lv Livermorium [298]		

Lanthanide Series	57 La Lanthanum 138.906	58 Ce Cerium 140.115	59 Pr Praseodymium 140.908	60 Nd Neodymium 144.24	61 Pm Promethium 144.913	62 Sm Samarium 150.36	63 Eu Europium 151.966	64 Gd Gadolinium 157.25	65 Tb Terbium 158.925	66 Dy Dysprosium 162.50	67 Ho Holmium 164.930	68 Er Erbium 167.26	69 Tm Thulium 168.934	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.967
Actinide Series	89 Ac Actinium 227.028	90 Th Thorium 232.038	91 Pa Protactinium 231.036	92 U Uranium 238.029	93 Np Neptunium 237.048	94 Pu Plutonium 244.064	95 Am Americium 243.061	96 Cm Curium 247.070	97 Bk Berkelium 247.070	98 Cf Californium 251.080	99 Es Einsteinium [254]	100 Fm Fermium 257.095	101 Md Mendelevium 258.1	102 No Nobelium 259.101	103 Lr Lawrencium [262]

Alkali Metal | Alkaline Earth | Transition Metal | Basic Metal | Semimetal | Nonmetal | Halogen | Noble Gas | Lanthanide | Actinide

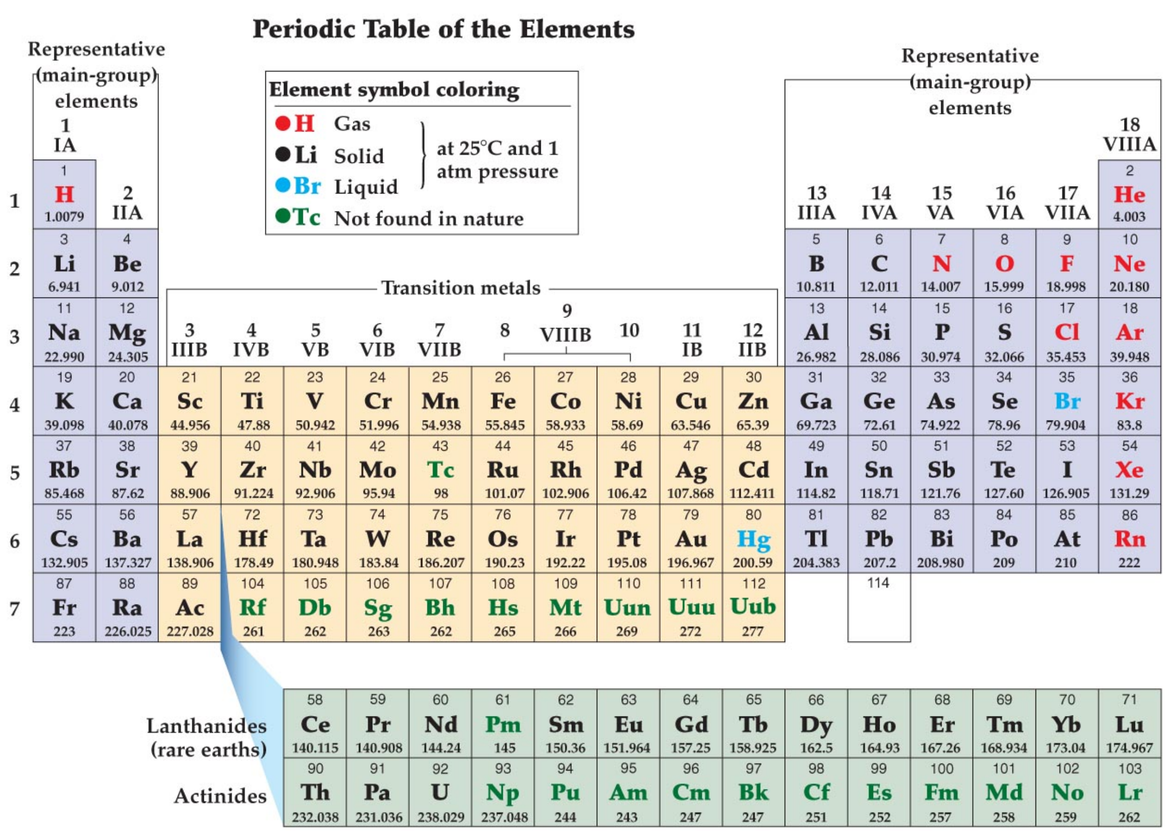
Metallic Character

- Most elements are metals (shiny, malleable, ductile, good conductors)
- Some are non-metals (dull, brittle, not-ductile, poor conductors)
- Seven are metalloids (kinda shiny, somewhat malleable, sorta ductile, semi-conductors)



Periodic Table

- We call each horizontal row a period.
- We call each vertical column a family or group.
- We divide sections of the table into the representative elements, the transition metals and the inner transition metals.



Periodic Table

- Some families (groups) are important enough to have unique names.

Group	Name
1A	Alkali metals
2A	Alkaline earth metals
6A	Chalcogens
7A	Halogens
8A	Noble gases (or rare gases)

Periodic Table of the Elements

Element symbol coloring
- H Gas
- Li Solid
- Br Liquid
- Tc Not found in nature

(Gas, Solid, Liquid: at 25°C and 1 atm pressure)

Representative (main-group) elements: groups 1–2 and 13–18; Transition metals: groups 3–12

	1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8	9 VIIIB	10	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	1 H 1.0079																	2 He 4.003
2	3 Li 6.941	4 Be 9.012											5 B 10.811	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.180
3	11 Na 22.990	12 Mg 24.305											13 Al 26.982	14 Si 28.086	15 P 30.974	16 S 32.066	17 Cl 35.453	18 Ar 39.948
4	19 K 39.098	20 Ca 40.078	21 Sc 44.956	22 Ti 47.88	23 V 50.942	24 Cr 51.996	25 Mn 54.938	26 Fe 55.845	27 Co 58.933	28 Ni 58.69	29 Cu 63.546	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.922	34 Se 78.96	35 Br 79.904	36 Kr 83.8
5	37 Rb 85.468	38 Sr 87.62	39 Y 88.906	40 Zr 91.224	41 Nb 92.906	42 Mo 95.94	43 Tc 98	44 Ru 101.07	45 Rh 102.906	46 Pd 106.42	47 Ag 107.868	48 Cd 112.411	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.905	54 Xe 131.29
6	55 Cs 132.905	56 Ba 137.327	57 La 138.906	72 Hf 178.49	73 Ta 180.948	74 W 183.84	75 Re 186.207	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.967	80 Hg 200.59	81 Tl 204.383	82 Pb 207.2	83 Bi 208.980	84 Po 209	85 At 210	86 Rn 222
7	87 Fr 223	88 Ra 226.025	89 Ac 227.028	104 Rf 261	105 Db 262	106 Sg 263	107 Bh 262	108 Hs 265	109 Mt 266	110 Uun 269	111 Uuu 272	112 Uub 277		114				

Lanthanides (rare earths)	58 Ce 140.115	59 Pr 140.908	60 Nd 144.24	61 Pm 145	62 Sm 150.36	63 Eu 151.964	64 Gd 157.25	65 Tb 158.925	66 Dy 162.5	67 Ho 164.93	68 Er 167.26	69 Tm 168.934	70 Yb 173.04	71 Lu 174.967
Actinides	90 Th 232.038	91 Pa 231.036	92 U 238.029	93 Np 237.048	94 Pu 244	95 Am 243	96 Cm 247	97 Bk 247	98 Cf 251	99 Es 252	100 Fm 257	101 Md 258	102 No 259	103 Lr 262

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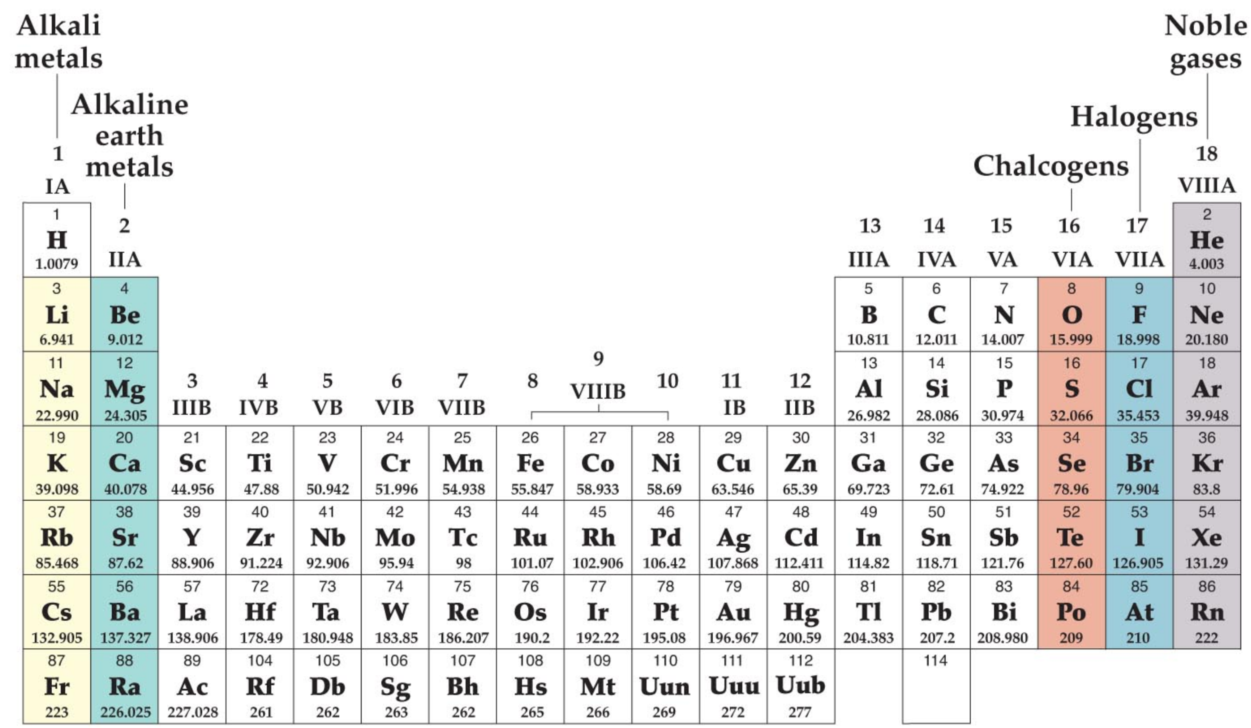

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87 Fr 223	88 Ra 226.025	89 Ac 227.028	104 Rf 261	105 Db 262	106 Sg 263	107 Bh 262	108 Hs 265	109 Mt 266	110 Uun 269	111 Uuu 272	112 Uub 277		114				

Atomic Theory

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  - The iterative nature of theory.
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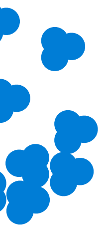

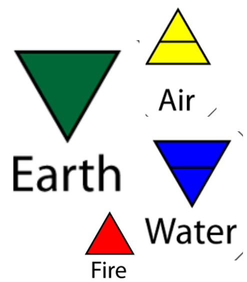

- Alchemy, Discovering Elements
  - Salt, Sulfur, and Mercury
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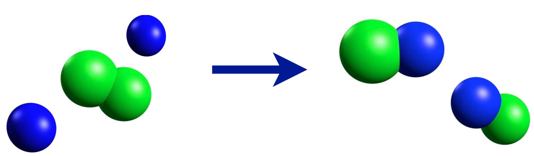

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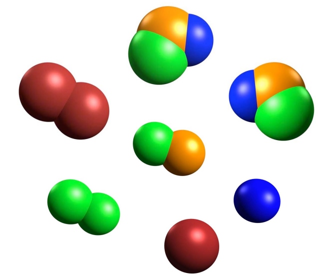
    - explaining compounds
    - the mole & molar mass



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3 Li	4 Be	5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg	13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca						

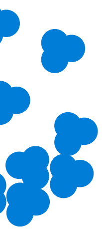
Official Class Periodic Table

Unless directed otherwise, use only this table for all classwork.
This table will be provided with all exams.

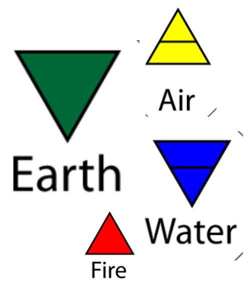
	1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIII	9 VIII	10 VIII	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	1 **H** 1.01 hydrogen																	2 **He** 4.00 helium
2	3 **Li** 6.94 lithium	4 **Be** 9.01 beryllium											5 **B** 10.81 boron	6 **C** 12.01 carbon	7 **N** 14.01 nitrogen	8 **O** 16.00 oxygen	9 **F** 19.00 fluorine	10 **Ne** 20.18 neon
3	11 **Na** 22.99 sodium	12 **Mg** 24.31 magnesium											13 **Al** 26.98 aluminum	14 **Si** 28.09 silicon	15 **P** 30.97 phosphorus	16 **S** 32.07 sulfur	17 **Cl** 35.45 chlorine	18 **Ar** 39.95 argon
4	19 **K** 39.10 potassium	20 **Ca** 40.08 calcium	21 **Sc** 44.96 scandium	22 **Ti** 47.88 titanium	23 **V** 50.94 vanadium	24 **Cr** 52.00 chromium	25 **Mn** 54.94 manganese	26 **Fe** 55.85 iron	27 **Co** 58.93 cobalt	28 **Ni** 58.69 nickel	29 **Cu** 63.55 copper	30 **Zn** 65.39 zinc	31 **Ga** 69.72 gallium	32 **Ge** 72.61 germanium	33 **As** 74.92 arsenic	34 **Se** 78.96 selenium	35 **Br** 79.90 bromine	36 **Kr** 83.80 krypton
5	37 **Rb** 85.47 rubidium	38 **Sr** 87.62 strontium	39 **Y** 88.91 yttrium	40 **Zr** 91.22 zirconium	41 **Nb** 92.91 niobium	42 **Mo** 95.94 molybdenum	43 **Tc** (99) technetium	44 **Ru** 101.07 ruthenium	45 **Rh** 102.91 rhodium	46 **Pd** 106.42 palladium	47 **Ag** 107.87 silver	48 **Cd** 112.41 cadmium	49 **In** 114.82 indium	50 **Sn** 118.71 tin	51 **Sb** 121.75 antimony	52 **Te** 127.60 tellurium	53 **I** 126.90 iodine	54 **Xe** 131.29 xenon
6	55 **Cs** 132.91 cesium	56 **Ba** 137.33 barium	57 **La** 138.91 lanthanum	72 **Hf** 178.49 hafnium	73 **Ta** 180.95 tantalum	74 **W** 183.85 tungsten	75 **Re** 186.21 rhenium	76 **Os** 190.2 osmium	77 **Ir** 192.22 iridium	78 **Pt** 195.08 platinum	79 **Au** 196.97 gold	80 **Hg** 200.59 mercury	81 **Tl** 204.38 thallium	82 **Pb** 207.2 lead	83 **Bi** 208.98 bismuth	84 **Po** (209) polonium	85 **At** (210) astatine	86 **Rn** (222) radon
7	87 **Fr** (223) francium	88 **Ra** (226) radium	89 **Ac** (227) actinium	104 **Rf** (261) rutherfordium	105 **Db** (262) dubnium	106 **Sg** (263) seaborgium	107 **Bh** (262) bohrium	108 **Hs** (265) hassium	109 **Mt** (266) meitnerium	110 **Ds** (281) darmstadtium	111 **Rg** (280) roentgenium	112 **Cn** (285) copernicium	113 **—** (284)	114 **Fl** (289) flerovium	115 **—** (288)	116 **Lv** (292) livermorium	117* **—** (294)	118 **—** (294)

58 **Ce** 140.12 cerium	59 **Pr** 140.91 praseodymium	60 **Nd** 144.24 neodymium	61 **Pm** (147) promethium	62 **Sm** 150.36 samarium	63 **Eu** 151.97 europium	64 **Gd** 157.25 gadolinium	65 **Tb** 158.93 terbium	66 **Dy** 162.50 dysprosium	67 **Ho** 164.93 holmium	68 **Er** 167.26 erbium	69 **Tm** 168.93 thulium	70 **Yb** 173.04 ytterbium	71 **Lu** 174.97 lutetium
90 **Th** (232) thorium	91 **Pa** (231) protactinium	92 **U** (238) uranium	93 **Np** (237) neptunium	94 **Pu** (244) plutonium	95 **Am** (243) americium	96 **Cm** (247) curium	97 **Bk** (247) berkelium	98 **Cf** (251) californium	99 **Es** (252) einsteinium	100 **Fm** (257) fermium	101 **Md** (258) mendelevium	102 **No** (259) nobelium	103 **Lr** (260) lawrencium

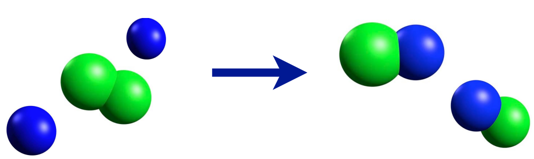
Atomic Theory



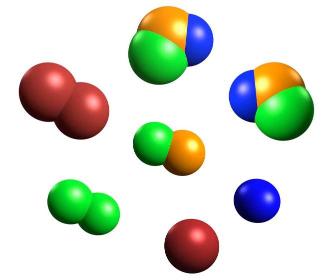
- Scientific Method
  - The iterative nature of theory.
- The Greek Contribution
  - Atomic Theory 1.0
    - The idea of Atoms
  - Elemental Theory



- Alchemy, Discovering Elements
  - Salt, Sulfur, and Mercury
  - The theory of Phlogiston
  - Discovery of Oxygen
  - Laws of Stoichiometry
    - The Law of Conservation of Mass
    - The Law of Constant Composition
    - The Law of Multiple Proportions



- Renaissance of the Atom
  - Atomic Theory 2.0
    - explaining compounds
    - the mole & molar mass



- Mendeleev, the Periodic Table
  - Periodicity
    - Patterns of elements
  - The Periodic Table
    - Metals & Non-metals
    - Representative Elements
    - Periods, Groups & Families
  - Class Periodic Table

1 H							2 He
3 Li	4 Be	5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg	13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca						

Questions?