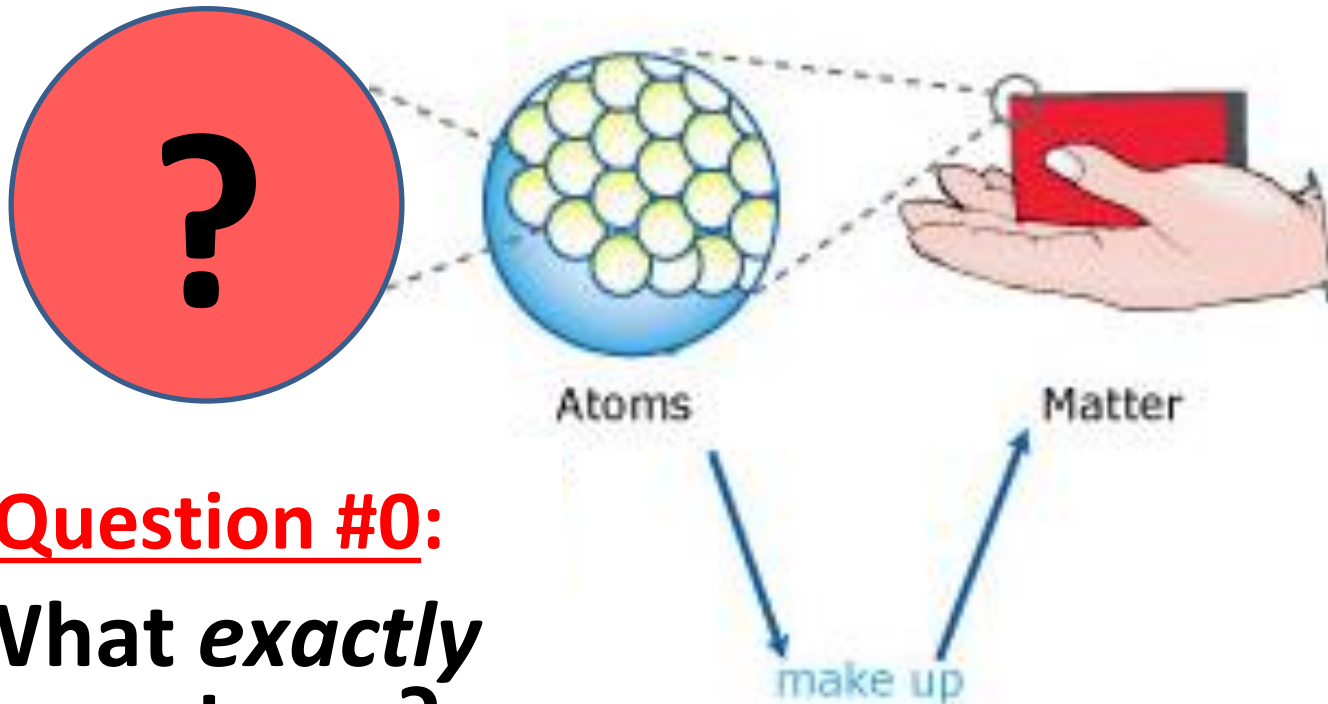


Structure of Matter



Question #0:

What *exactly*
are atoms?

Are they all the same?

If not, what
makes them
different?

Atomic Theory Development

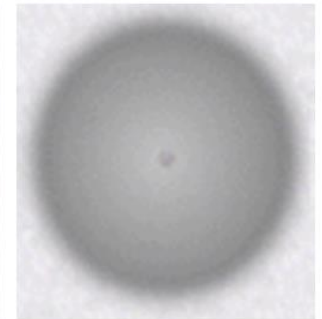
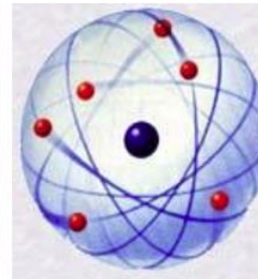
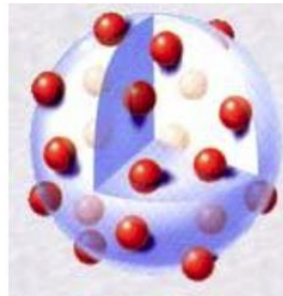
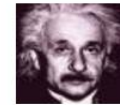
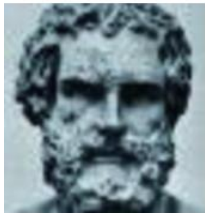
Democritus 460 BC
and Dalton 1803 AD

Thomson
1897

Rutherford
1912

Bohr
1913

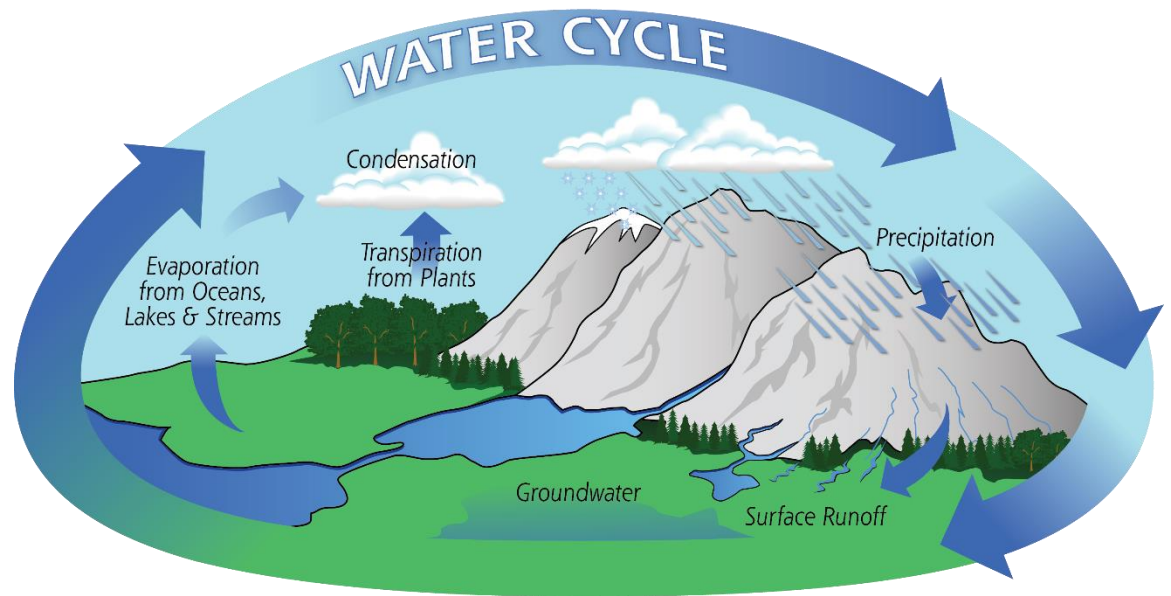
Modern
Quantum
Cloud Model
post 1930



Born **as early as 400 BC**, it took more than 2000 years before Science was ready to accept the idea of atomic structure of matter...and another 150 years to develop a good *model!*

What is a Model?

In Science, a model is a physical, mathematical, or conceptual (abstract) representation of a real phenomenon that is difficult to observe directly – that is, a *convenient substitute*.

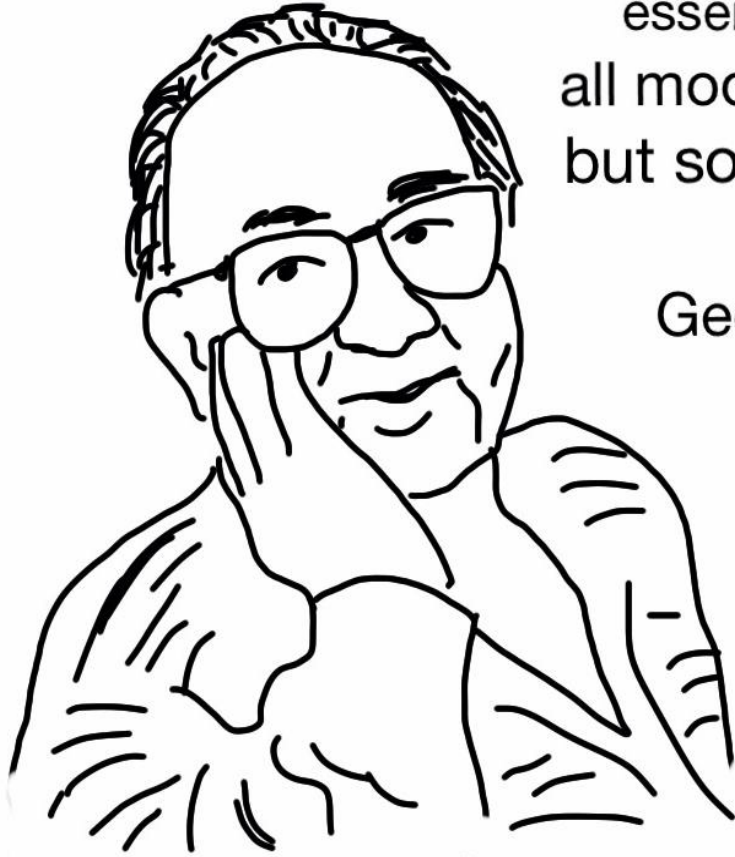


Scientific **models** are used in a variety of scientific disciplines to explain and predict the behavior of real objects or systems.

A Model is Never Perfect

essentially,
all models are wrong,
but some are useful

George E. P. Box



*(one of the most
influential
statisticians of
the 20th century)*



Scientific models
are **approximations**
of the objects and
systems that they
represent!

Scientists are constantly working to **improve and refine** models.

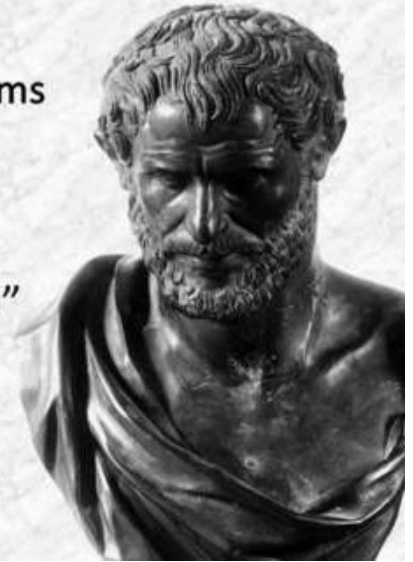
Democritus

~400 BC

“atomos”=“not to be cut”

“Nothing exists except atoms
and empty space;
everything else is opinion”

Democritus
(ca. 460 BC – ca. 370 BC)



- Matter **could not** be divided into smaller and smaller pieces forever, eventually the **smallest possible piece** would be obtained.
- This piece, **atomos** (atom), would be **indivisible**.
- Between atoms, there would be **empty space**.
- To Democritus, atoms were **small, hard particles of different shapes and sizes** that were **all made of the same material**.
- Atoms were infinite in number, always moving and capable of joining together.

John Dalton

early 1800s



The **first truly scientific theory of the atom**: conclusions were reached by experimentation and examination of the results in an empirical fashion.

- All **elements** are composed of **atoms**.
- Atoms are indivisible and indestructible particles.
- Atom model: a billiard ball or a *marble*.

- H**
O
W
?
- Atoms of the same element are exactly alike.
 - Atoms of different elements are different.
 - Compounds are formed by the joining of atoms of two or more elements.



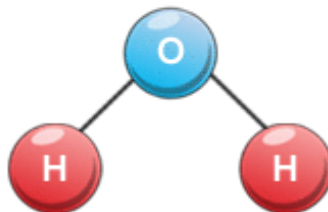
Color?
Size?

Mass?

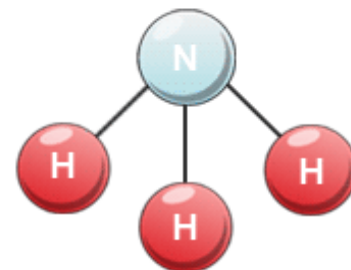
How to find Atomic Weight?

- Assumption #1: atoms of a given chemical element are identical in size, **mass**, and all other properties.
- Assumption #2: chemical **compounds** are formed when atoms of different elements combine in simple whole-number ratios.

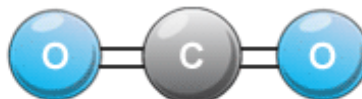
WATER



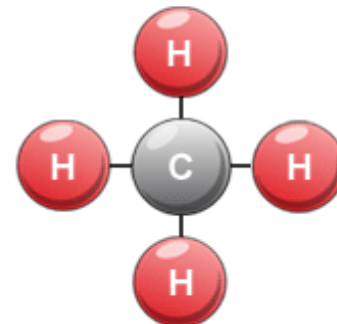
AMMONIA



CARBON
DIOXIDE



METHANE



Atomic weights of elements can be determined by careful **weighing** of chemical reactions!

John Dalton

- 1803-1805: **first list** of **relative atomic weights** containing just **6 elements**, namely *hydrogen* (conventionally assumed to weigh 1), *oxygen*, *nitrogen*, *carbon*, *sulfur*, and *phosphorus*.

- 1808: expanded list of elements

ELEMENTS			
○	Hydrogen 1	⊕	Strontian 46
⊖	Nitrogen 5	⊗	Barytes 68
●	Carbon 5	⊙	Iron 50
○	Oxygen 7	⊙	Zinc 56
⊖	Phosphorus 9	⊙	Copper 56
⊕	Sulphur 13	⊕	Lead 90
⊖	Magnesia 20	⊙	Silver 190
⊖	Lime 24	⊕	Gold 190
⊕	Soda 28	⊙	Platina 190
⊕	Potash 42	⊕	Mercury 167

Dmitri Mendeleev

- 1869: **periodic table** of **66 elements** ordered and grouped according to their atomic weight.

ОПЫТЪ СИСТЕМЫ ЭЛЕМЕНТОВЪ.					
ОСНОВАННОЙ НА ВѢСЪ 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	Ru = 104,4	Ir = 198.		
	Ni = 59	Pd = 106,4	Os = 199.		
H = 1	Cu = 63,4	Ag = 108	Hg = 200.		
Be = 9,4	Mg = 24	Zn = 65,4	Cd = 112		
B = 11	Al = 27,4	? = 68	U = 116	Au = 197,7	
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 = 35,4	Br = 80	I = 127		
Li = 7	Na = 23	K = 39	Rb = 85,4	Cs = 133	Tl = 204.
		Ca = 40	Sr = 87,4	Ba = 137	Pb = 207.
		? = 45	Ce = 92		
		?Er = 56	La = 94		
		?Yt = 60	Di = 95		
		?In = 75,4	Th = 118?		

Д. Менделѣевъ

Scientific Mysteries of 1870s

LIGHTEST

1 H Hydrogen 1	Atomic # Symbol Name Atomic weight
3 Li Lithium 7	4 Be Beryllium 9
11 Na Sodium 23	12 Mg Magnesium 24

Elements are grouped and *ordered* according to their **atomic weight**...

Fragment of the Periodic Table (showing elements known by 1869 when Mendeleev published his first version)

5 B Boron 11	6 C Carbon 12	7 N Nitrogen 14	8 O Oxygen 16	9 F Fluorine 19	10 He Helium 4.002602
13 Al Aluminium 27	14 Si Silicon 28	15 P Phosphorus 31	16 S Sulfur 32	17 Cl Chlorine 35	18 Ar Argon 39.948
31 Ga Gallium 69.723	32 Ge Germanium 72.64	33 As Arsenic 75	34 Se Selenium 79	35 Br Bromine 80	36 Kr Krypton 83.795
49 In Indium 115	50 Sn Tin 118	51 Sb Antimony 122	52 Te Tellurium 128	53 I Iodine 127	54 Xe Xenon 131.293

UNKNOWN

...but not always!

Puzzling question: what carries electricity?