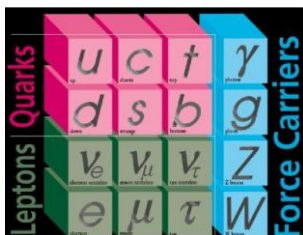


## Welcome to PHY101: What is matter?



<http://www.d0.fnal.gov/Run2Physics/WWW/results/fnal/NP/N04C>

## Lecture 1: What is science?

• Science is the body of knowledge that describes the order within nature and the causes of that order

• Science is an activity dedicated to gathering of knowledge about the world and organizing and condensing it into testable laws and theories using the *Scientific Method*

### The Scientific Method

- 1) Observe the world around you
- 2) Frame a question and formulate a hypothesis
- 3) Make a prediction based on the your hypothesis
- 4) Test your prediction with an experiment
- 5) If prediction is *falsified*, formulate another hypothesis; if prediction is validated, make more predictions

Pioneer of the Scientific Method: Ibn al-Haytham (Alhazen, 965-1039)

## Lecture 1: What is science/physics?

• A hypothesis is scientific only if it is *falsifiable*!

“No number of experiments can prove me right; a single experiment can prove me wrong.” –Albert Einstein

• Science versus Pseudoscience

• What is physics? It’s the study of nature, which is made up of matter and energy, and how “pieces” of nature interact with one another via a few fundamental laws.

## The atomic hypothesis: The Greeks

Question: Is matter infinitely divisible or is there a point at which it can be divided no further?

Atoms must be made of imperishable stuff into which everything can be resolved in the end, so that there may be a stock of matter for building the world anew. The atoms, therefore, are absolutely solid and unalloyed. In no other way could they have survived...to keep the world in being. ---Lucretius

Artistotle did not agree with the atomic hypothesis.

## The atomic hypothesis: Dalton

Dalton’s five chemical principles:

- 1) Matter is made up of individual atoms
- 2) Each chemical element is made up of identical atoms of a particular kind
- 3) Atoms are unchangeable
- 4) Chemical elements may combine to form compounds
- 5) Chemical reactions rearrange atoms into different compounds, but not change the numbers of each element

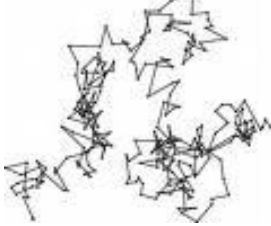
Leads to Dalton’s *law of multiple proportions*: When two elements combine they do so in a ratio of whole numbers.

## Dalton’s periodic table

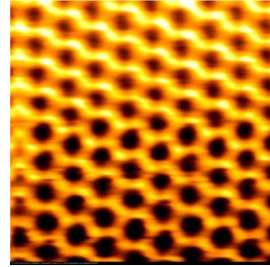
ELEMENTS			
Hydrogen	1	Strontian	86
Azote	5	Barytes	68
Carbon	5	Lion	50
Oxygen	7	Zinc	56
Phosphorus	9	Copper	56
Sulphur	13	Lead	90
Magnesia	20	Silver	190
Lime	24	Gold	190
Soda	28	Platina	190
Potash	41	Mercury	167

## Experimental evidence for atoms

Brownian motion: In 1827, botanist John Brown watched pollen grains floating on water through his microscope. What did he see?

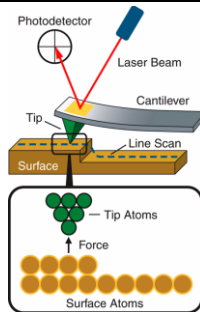


## More experimental evidence



Dr. F. J. Giessibl, University of Regensburg

## Atomic force microscope



<http://nano.tm.agilent.com/blog/wp-content/>

## Atoms are numerous

Avogadro's number is the number of molecules in 1 mole of any substance. It is equal to

$$6.022 \times 10^{23} \text{ mol}^{-1}.$$

Perrin in 1908 conducted the first measurement of Avogadro's number using Brownian motion. He obtained

$$7.15 \times 10^{23} \text{ mol}^{-1}.$$

<http://www.particle.kth.se/fmi/kurs/PhysicsSimulation/Images/6b/fysikb1.jpg>

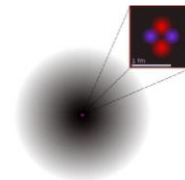
## What is the structure of the atom?



Thomson: Plum pudding model where electrons are the raisins and pudding is the positively charged matter.

## Atomic structure

Experiments by Rutherford in 1919 indicated that the positively charged matter was concentrated at the center of the atom---in the nucleus of the atom



# Periodic Table of Elements

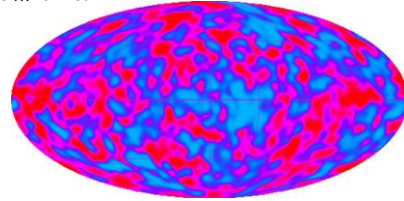
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	H Hydrogen 1.00794																	He Helium 4.002602
2	Li Lithium 6.941	Be Beryllium 9.012182											B Boron 10.811	C Carbon 12.0107	N Nitrogen 14.006434	O Oxygen 15.999	F Fluorine 18.9984032	Ne Neon 20.1797
3	Na Sodium 22.98976928	Mg Magnesium 24.304											Al Aluminum 26.9815386	Si Silicon 28.0855	P Phosphorus 30.973762	S Sulfur 32.06	Cl Chlorine 35.45	Ar Argon 39.948
4	K Potassium 39.0983	Ca Calcium 40.078	Sc Scandium (44.955912)	Ti Titanium 47.88	V Vanadium 50.9415	Cr Chromium 51.9961	Mn Manganese 54.938044	Fe Iron 55.845	Co Cobalt 58.933195	Ni Nickel 58.6934	Cu Copper 63.546	Zn Zinc 65.38	Ga Gallium 69.723	Ge Germanium 72.630	As Arsenic 74.9216	Se Selenium 78.96	Br Bromine 79.904	Kr Krypton 83.80
5	Rb Rubidium 85.4678	Sr Strontium 87.62	Y Yttrium (88.90584)	Zr Zirconium 91.224	Nb Niobium 92.90638	Mo Molybdenum 95.94	Tc Technetium (98.90625)	Ru Ruthenium 101.07	Rh Rhodium 102.9055	Pd Palladium 106.36	Ag Silver 107.8682	Cd Cadmium 112.411	In Indium 114.818	Sn Tin 118.710	Sb Antimony 121.757	Te Tellurium 127.6	I Iodine 126.905	Xe Xenon 131.29
6	Cs Cesium 132.90545196	Ba Barium 137.327	La Lanthanum (138.90486)	Hf Hafnium 178.49	Ta Tantalum 180.94788	W Tungsten 183.84	Re Rhenium 186.207	Os Osmium 190.23	Ir Iridium 192.222	Pt Platinum 195.084	Au Gold 196.966569	Hg Mercury 200.59	Tl Thallium 204.3833	Pb Lead 207.2	Bi Bismuth 208.9804	Po Polonium (209)	At Astatine (210)	Rn Radon 222
7	Fr Francium (223)	Ra Radium (226)	Ac Actinium (227)	Rf Rutherfordium (261)	Db Dubnium (262)	Sg Seaborgium (263)	Bh Bohrium (264)	Hs Hassium (265)	Mt Meitnerium (266)	Ds Darmstadtium (267)	Rg Roentgenium (268)	Cn Copernicium (269)	Nh Nihonium (270)	Fm Fermium (271)	Md Mendelevium (272)	No Nobelium (273)	Lr Lawrencium (274)	Uub Ununbium (275)

For elements with no stable isotopes, the mass number of the isotope with the longest half-life is in parentheses.

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## Where did atoms come from?

Scientists have hypothesized that the origin of the universe started with empty vacuum. Quantum fluctuations of this vacuum triggered inflation and ultimately matter and energy formed.



Cosmic microwave background radiation