Chapter 2: ATOMS

Outline of today's class:

The atomic idea (example for the significance of "modern" physics)
Chemical elements, molecules, periodic table
Temperature/warmth
Units & powers of ten
Examples of chemical reactions

Can you split an atom (“átomos” – indivisible)?

(a)Yes (b) No

Yes - removing *negatively charged electron(s)* from the *positively charged nuclei* is referred to as *ionization*.

An atom is mostly “empty” space.

(a) True (b) False

True – atomic nuclei are typically 10,000 (10^4) times smaller than atoms (and yet the nuclei contain >99% of the atomic mass, i.e. are extremely dense!)

Chapter 2: ATOMS

"átomos" – indivisible…well, in the end our "atom' is quite divisible - electrons & nuclei (protons & neutrons, themselves composed of "quarks")

In fact, atoms are mostly empty space! (see later)

If, in some cataclysm, all of scientific knowledge were to be destroyed, and only one sentence passed on to the next generations of creatures, what statement would contain the most information in the fewest words? I believe it is . . . that all things are made of atoms—little particles that move around in perpetual motion, attracting each other when they are a little distance apart, but repelling each other upon being squeezed into one another. In that one sentence . . . there is an enormous amount of information about the world.

Richard Feynman, Physicist

Important: …"little particles" … "in perpetual motion"
See the class homepage for more from Feynman.

“pollen grains” jiggle **perpetually** in room temperature water

http://www.youtube.com/watch?v=2Vdjin734gE “Brownian Motion”

Viewed through a microscope...**why are they jiggling???**

http://galileo.phys.virginia.edu/classes/109N/more_stuff/Applets/brownian/brownian.html

The Atomic Theory of Matter

All matter is made of tiny particles, too small to be seen. (With the naked eye!)

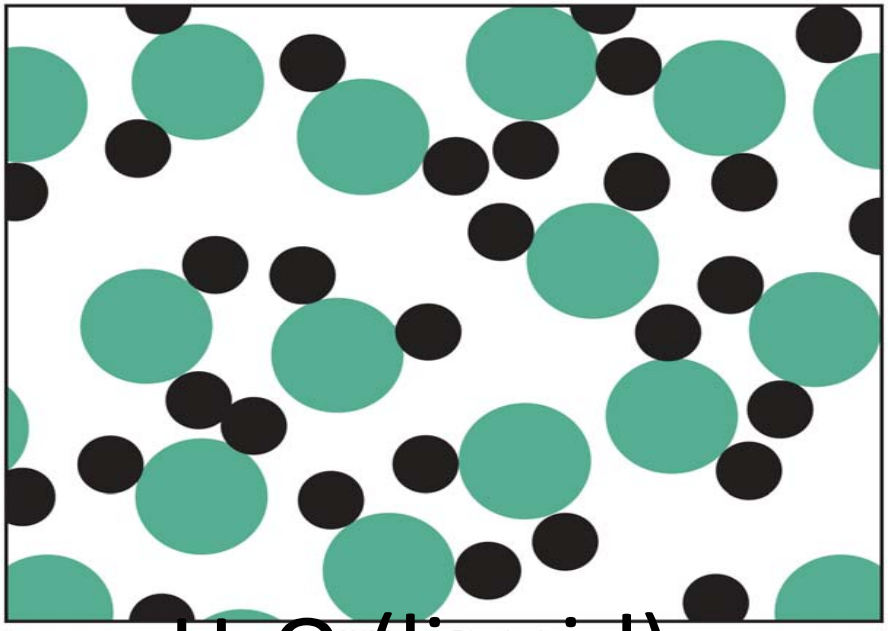
Relevant terms in connection with atoms:

(chemical) element – atom is the smallest particle;

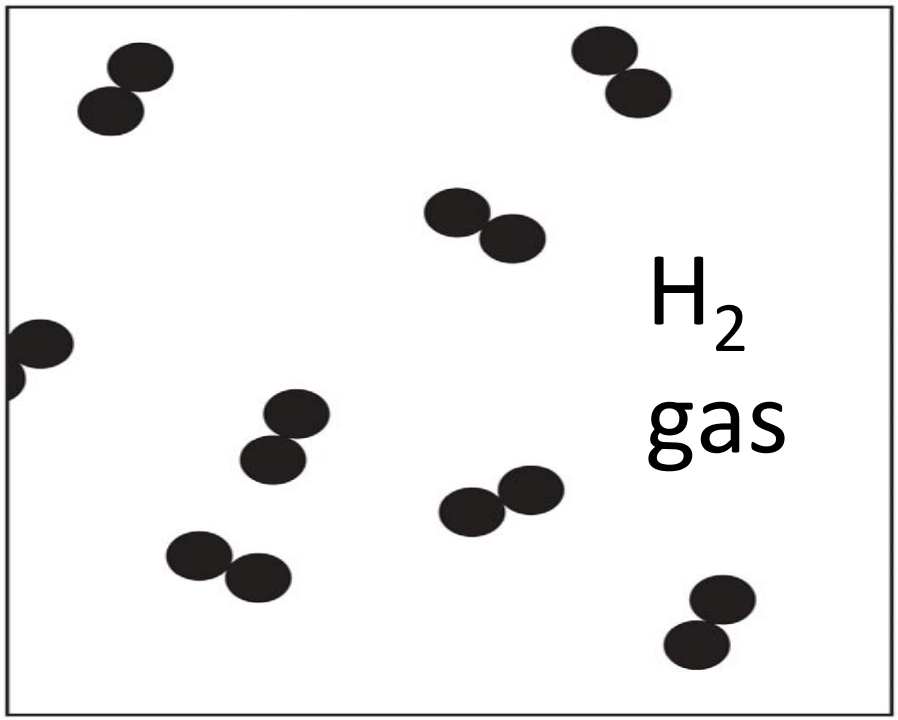
atomic #; molecule; chemical compound;

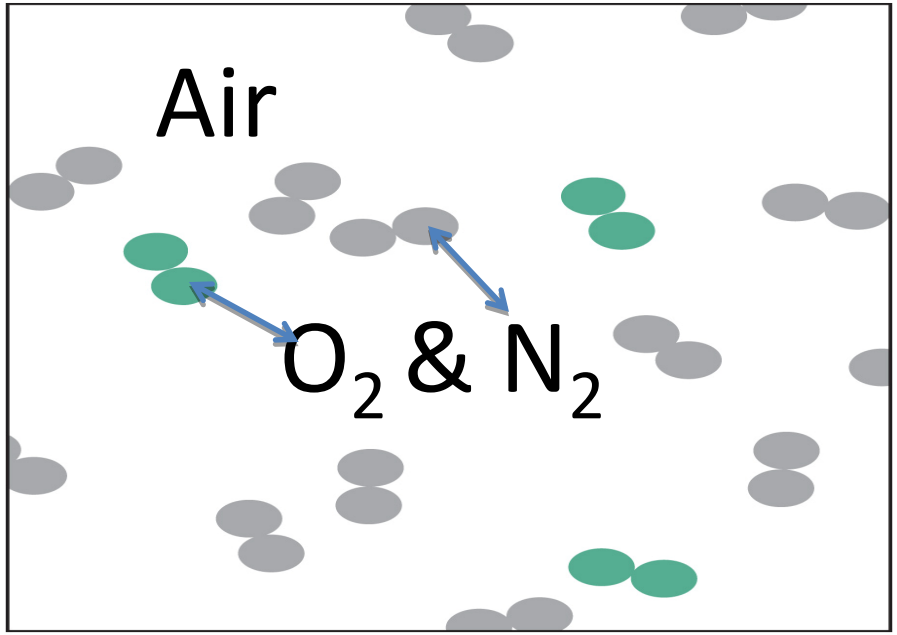
Periodic table

Perhaps surprising: Many (in fact, most!) types of atoms are unstable. Their nucleus decays into other nuclei & particles, called *radioactivity* (chapter 14).



H_2O (liquid)





Periodic table of the elements

1 H Hydrogen																2 He Helium
3 Li Lithium	4 Be Beryllium						**METALS**				5 B Boron	6 C Carbon	7 N Nitrogen	8 O Oxygen	9 F Fluorine	10 Ne Neon
11 Na Sodium	12 Mg Magnesium						Transition Metals				13 Al Aluminum	14 Si Silicon	15 P Phosphorus	16 S Sulfur	17 Cl Chlorine	18 Ar Argon
19 K Potassium	20 Ca Calcium	21 Sc Scandium	22 Ti Titanium	23 V Vanadium	24 Cr Chromium	25 Mn Manganese	26 Fe Iron	27 Co Cobalt	28 Ni Nickel	29 Cu Copper	30 Zn Zinc	31 Ga Gallium	32 Ge Germanium	33 As Arsenic	34 Se Selenium	35 Br Bromine	36 Kr Krypton
37 Rb Rubidium	38 Sr Strontium	39 Y Yttrium	40 Zr Zirconium	41 Nb Niobium	42 Mo Molybdenum	43 Tc Technetium	44 Ru Ruthenium	45 Rh Rhodium	46 Pd Palladium	47 Ag Silver	48 Cd Cadmium	49 In Indium	50 Sn Tin	51 Sb Antimony	52 Te Tellurium	53 I Iodine	54 Xe Xenon
55 Cs Cesium	56 Ba Barium	57–71*	72 Hf Hafnium	73 Ta Tantalum	74 W Tungsten	75 Re Rhenium	76 Os Osmium	77 Ir Iridium	78 Pt Platinum	79 Au Gold	80 Hg Mercury	81 Tl Thallium	82 Pb Lead	83 Bi Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
87 Fr Francium	88 Ra Radium	89–103†	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaburgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Ds Darmstadtium	111 Rg Roentgenium	112#	113#	114#	115#	116#		118#
*Lanthanides (Rare Earth Metals)			57 LA Lanthanum	58 Ce Cerium	59 Pr Praseodymium	60 Nd Neodymium	61 Pm Promethium	62 Sm Samarium	63 Eu Europium	64 Gd Gadolinium	65 Tb Terbium	66 Dy Dysprosium	67 Ho Holmium	68 Er Erbium	69 Tm Thulium	70 Yb Ytterbium	71 Lu Lutetium
†Actinides			89 Ac Actinium	90 Th Thorium	91 Pa Protactinium	92 U Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lw Lawrencium

The

CONCEPT CHECK 5 What elements, and how many atoms of each, does the simple sugar $C_6H_{12}O_6$ ("glucose") contain? (a) 6 chlorine, 12 helium, 6 ozone. (b) 6 carbon, 12 hydrogen, 6 oxygen. (c) 1 chlorine, 1 hydrogen, 1 oxygen. (d) 1 carbon, 1 hydrogen, 1 oxygen. (e) 1 carbon, 2 hydrogen, 1 oxygen.

Concept Check 6 The chemical formula for carbon dioxide is (a) CaO; (b) Ca_2O; (c) CO; (d) CO_2 ; (e) C_2O

Atomic theory links macroscopic & microscopic world.

Macroscopic states of matter:

solid – liquid – gas (& some exotics)

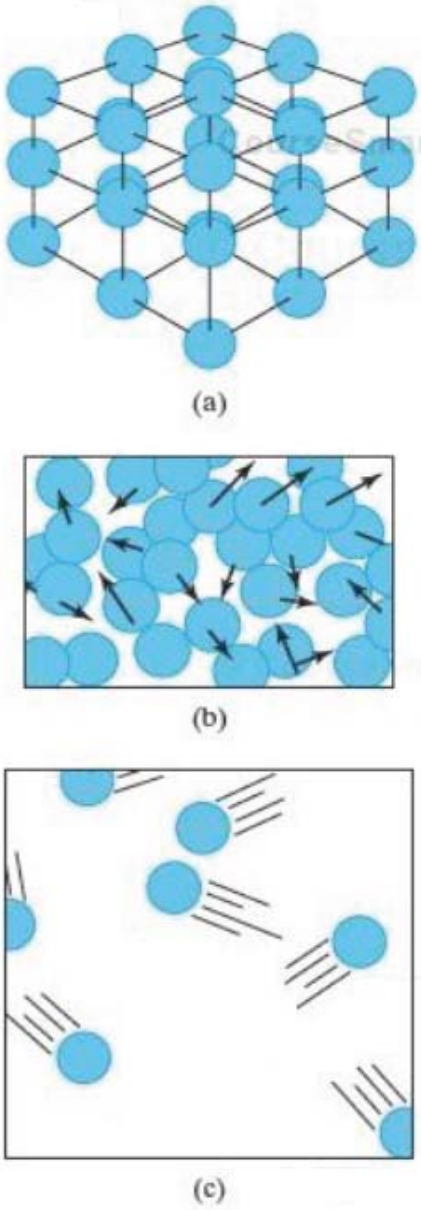


Figure 2.9
Microscopic views of the (a) solid, (b) liquid, and (c) gas states of matter.

Important concept:

Temperature (warmth) = Thermal Motion
(random, disorganized, molecular motion)

→Don't mix up temperature & pressure!
(pressure is a "force" – more on forces soon)

Demos: Balloon expanding
Squirt perfume

Units – important in physics since we're dealing with measuring quantities. m(eters), g(rams), s(econds), and powers thereof such as km, kg, ns, etc.

Powers of 10 ("scientific notation"): Familiar?

Why useful? Need examples?

Omission in book: $10^0 = 1$

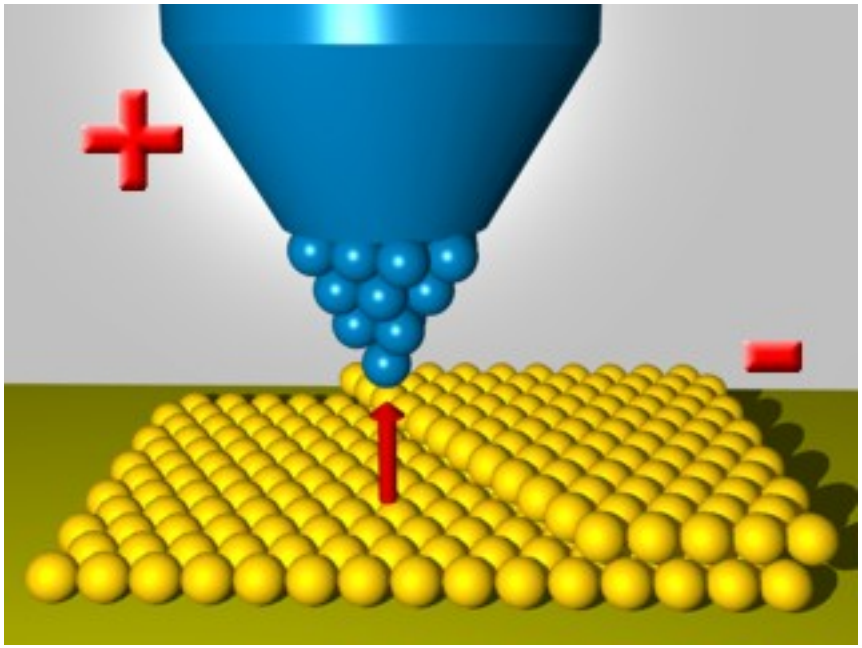
Worth remembering: atoms are tiny! ~10^{-10} m(1/10 of 1 nm)

Remarkable: nowadays possible to see individual atoms!
(see p. 43 on scanning microscopes)

Field emission demo

Corollary: given their smallness there are lots of them in even a small chunk of matter – 1 liter of air ~10^{22} molecules!
(air: ~80% N_2, ~20% O_2, traces of other stuff)

Scanning Tunneling Microscope (STM)

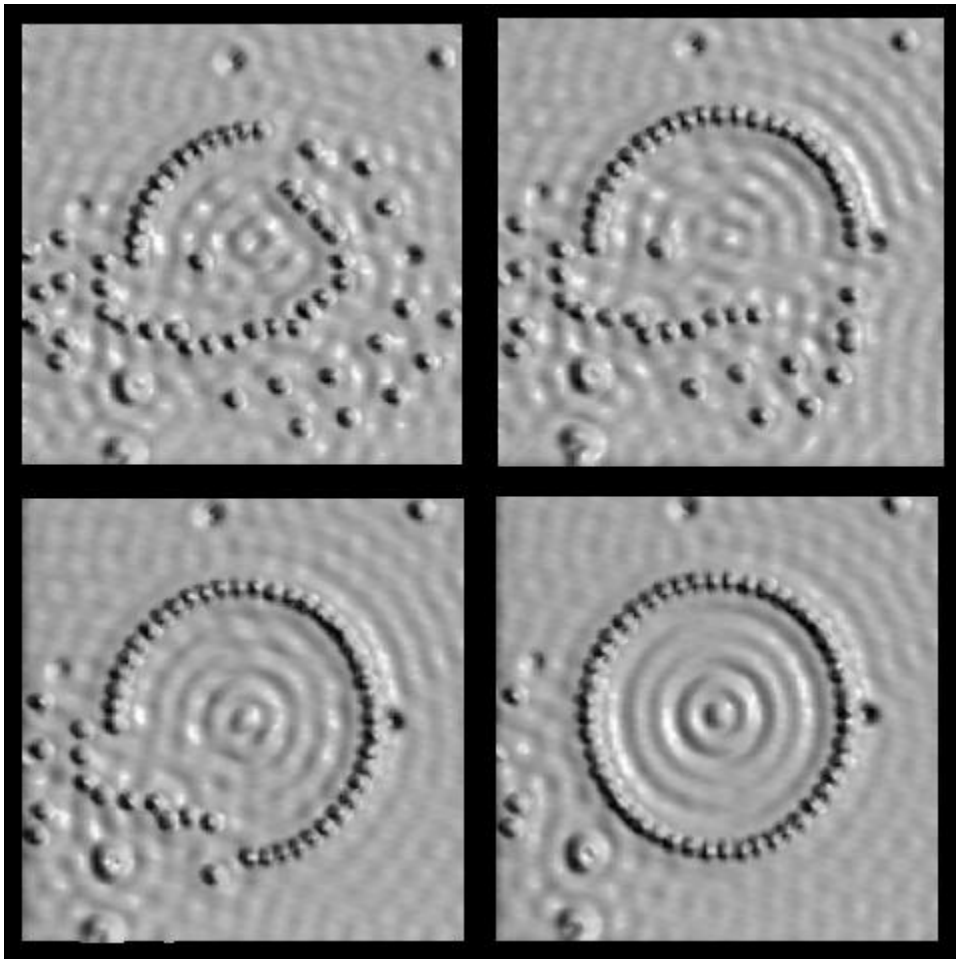


http://www.ieap.uni-kiel.de/surface/ag-berndt/mikro/images/stm-320.jpg

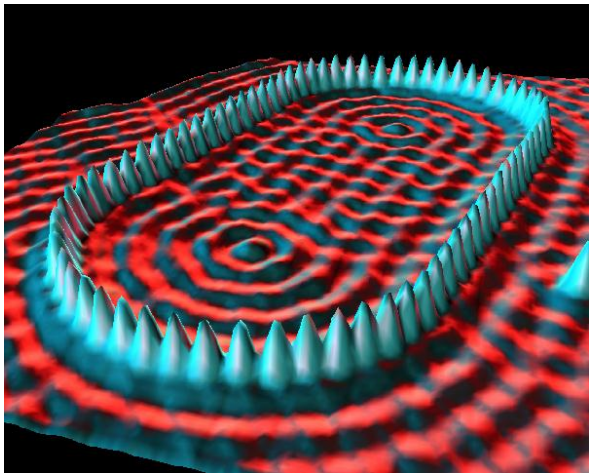
Invented in the early 1980s

Electrons moving across a very narrow gap onto a very sharp tip.

STM can be used to build fun things one atom at a time



Iron atoms on copper crystal



http://www.almaden.ibm.com/vis/stm/corral.html

A couple important chemical reactions (2.8):
(atoms & molecules do matter!)

Methane (natural gas) burning:

$CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$

Photosynthesis:

$6\ CO_2 + 6\ H_2O + \text{solar energy} \rightarrow C_6H_{12}O_6 + 6\ O_2$ (glucose)

<u>Crucial</u> implication: nearly all of our oxygen comes from plants via photosynthesis!

Note: This is the inverse of metabolism in your body, whereby the burning of glucose/sugar gives you energy.

Conceptual Exercises:

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A: B & C could be compounds. Example: $H_2SO_4 \rightarrow H_2 + SO_4$.
But B & C could also be elements. Example: $HCl \rightarrow H + Cl$.
On the other hand, A must clearly be a compound.

24. Why is it difficult to remove the lid from a vacuum-sealed jar?

A: Outside air pushes down on lid more strongly than inside air pushes up. Air pressure holds lid on the jar.

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A: Assume ~75 kg body weight. Therefore about $75/10^{-26}$ atoms, or 7.5×10^{27}. That's a lot!

45. No nitrogen in gasoline. So where does the NO_x pollutant in car exhaust come from?

A: From the atmosphere, i.e. air, which contains a lot of N_2. At the high engine temperatures N and O combine chemically.