

international baccalaureate
chemistry year 2:
year 1 review

The study of chemistry



why chemistry is awesome:

chemistry is :

a chemical is:

ok...what is matter?

compare mass and weight:

you?

air?

an idea?

energy?

religion?

a perfect vacuum?
a black hole?



chemists

what do chemists do? they all

what kind of chemist am I?

the branches of chemistry

carbon-based:
ex: plastics

not carbon-based
ex: mining

physical change:
ex: reaction rates

Medicines:
ex: viagra



analysis



I make aspirin: I am a
 chemist.

I analyze: I am an
 chemist

crime solvers:



I study the chemistry
of fruit flies, so I am
a chemist

chemistry of life:



I solve crimes using
chemistry: I am a
 chemist.



I make plastics: I am a
 chemist.

where does chemistry fit in?

basic

applied

physics

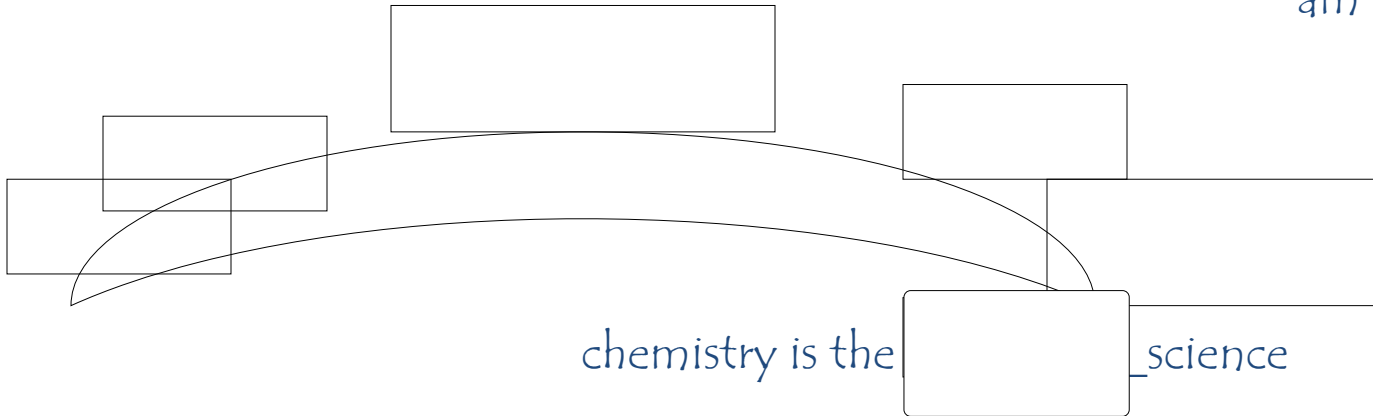
math

social science

chemistry

biology

I study physical processes: I
am a chemist



I study gold; this is
 chemistry



chemistry is the science

the "oh ec" scientific method



what might each letter stand for?

oh heck I know that

example:

pain medication study positive control:

negative control:

hypothesis:

theory:

law

C

O

E

H

supplemental terms: qualitative

quantitative

classification of matter

matter
 element, compound, or mixture?



gold



ocean



milk



copper



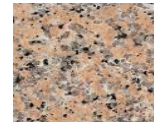
glass

nothing is pure in this world. what can we say about mixtures?

classify a drop of blood:



classify granite:



looks pure but isn't
 one thing visible

doesn't look pure
 multiple things visible

suggest a solution:

gas-gas:

solid-liquid:

gas-liquid:

liquid-liquid:

solid-solid:

either way it's still a mixture...until it is separated we don't know much about it.

a pure form of matter:

a sample containing more than one substance:

a substance that **cannot** be separated into simpler substances by *chemical means*:

a substance composed of atoms of two or more elements chemically united in fixed proportions.

purification: how would you separate these mixtures?

 <p>oil water</p> <p>oil/water</p>	 <p>wet sand</p>	<p>you have:</p>  <p>sugar/water</p>	 <p>oils</p>	 <p>???</p>
oil	dry sand	<p>want pure:</p> sugar	each pure oil	each pure solute

physical vs. chemical

p6

chemical property:

physical property:

suggest the property responsible and if it is physical or chemical:



boiling



rusting



melting



rising



burning



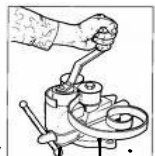
crystallizing



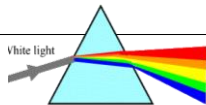
flattening



molding



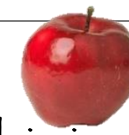
stretching



light bending



observing



shining

extensive and intensive properties



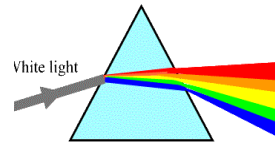
melting point



mass



density



refractive index

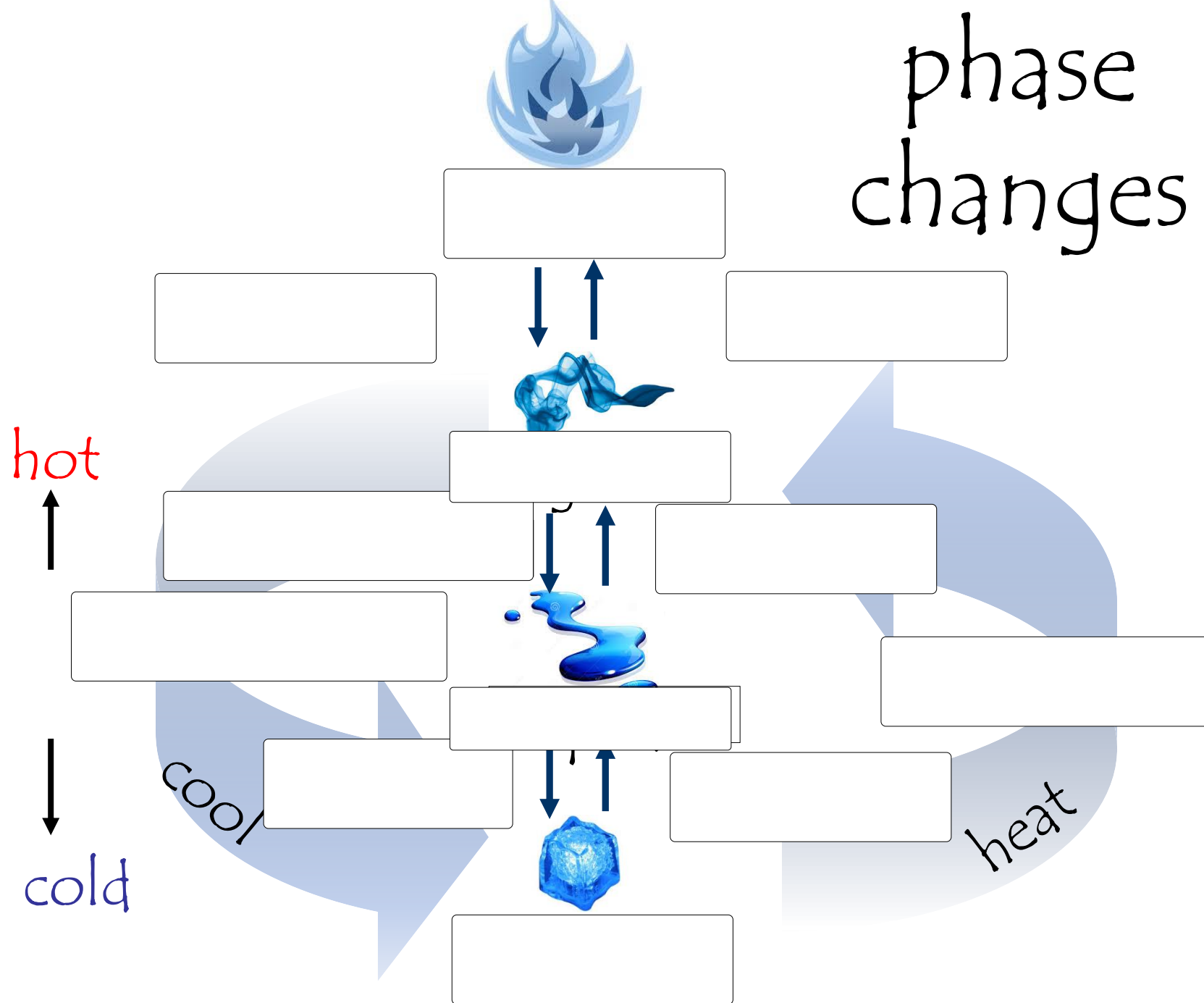


toxicity

crystalline or
amorphous?



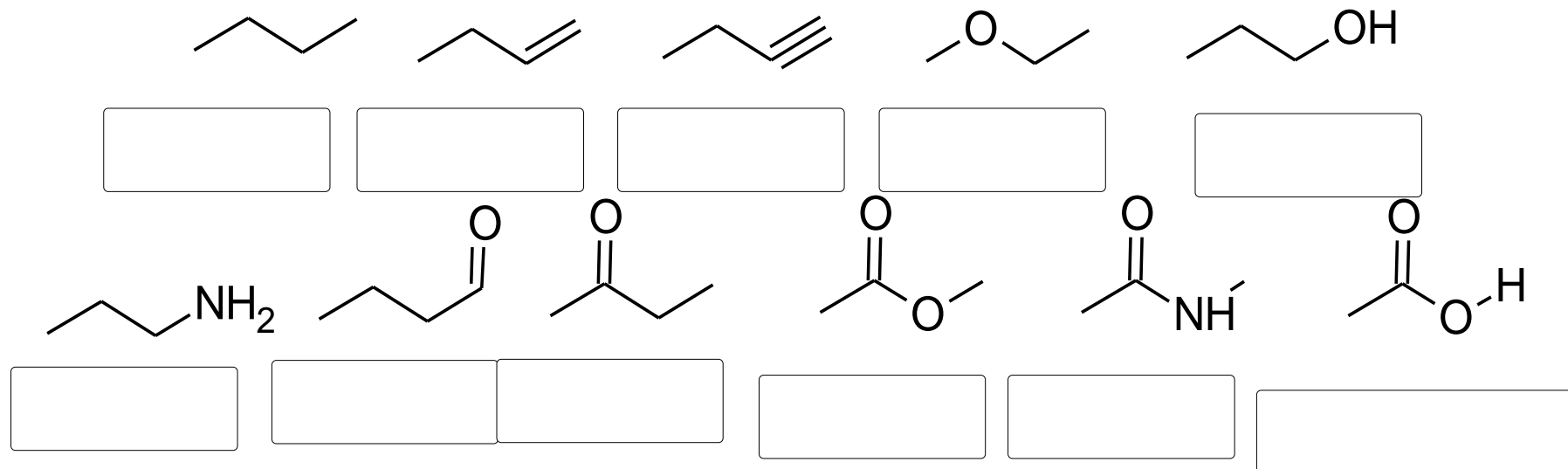
phase changes



organic functional groups

Here are the skeletal formulas of some common types of organic compounds, known as functional groups.

what types of organic molecules are there?

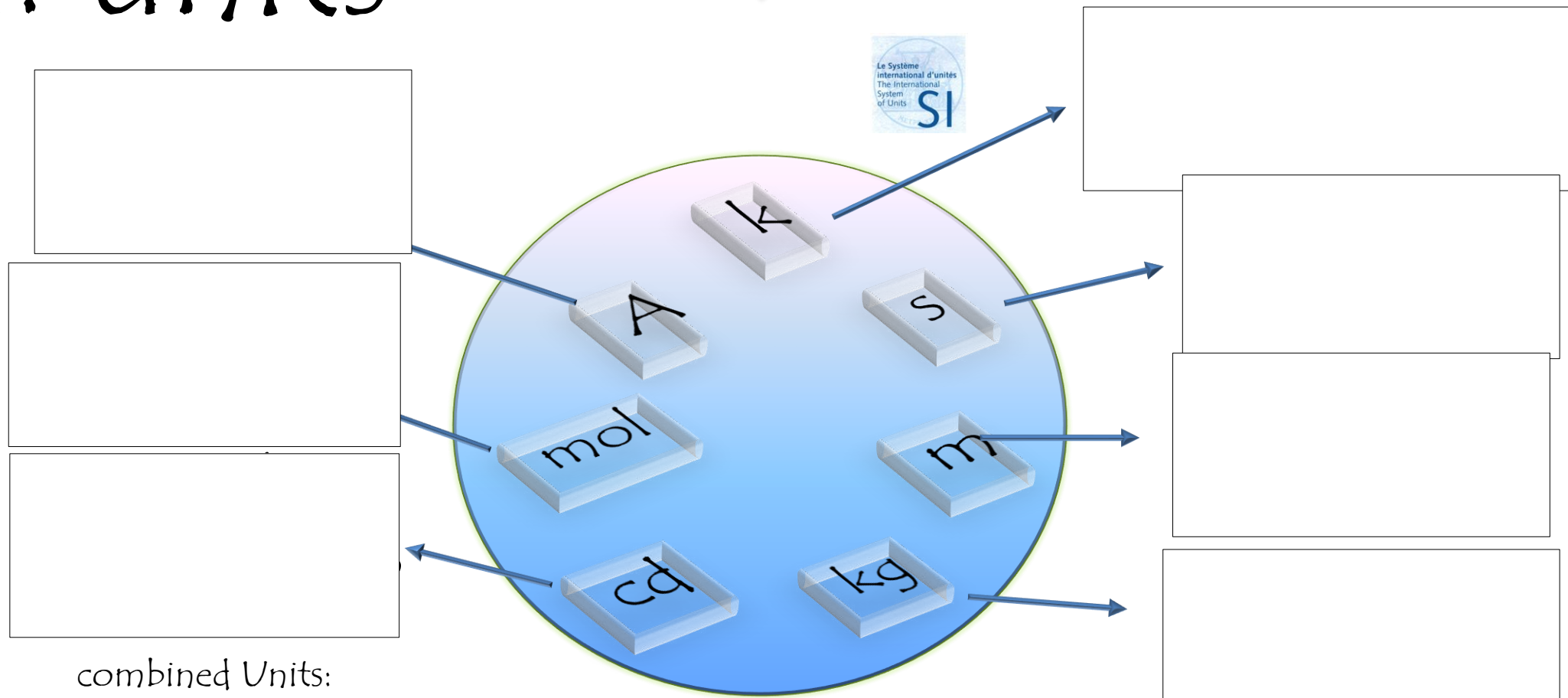


The groups shown above generally contain **more hydrogen** and **less oxygen** as one reads across from alkanes to carboxylic acids: they become **more oxidized**.

Each student should be able to recognize and draw these functional groups.

s.i. units

s.i. units: le systeme internationale



combined Units:

speed acceleration volume

density

density formula:

density

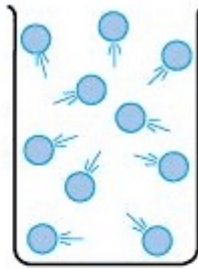
= mass/volume



g/mL

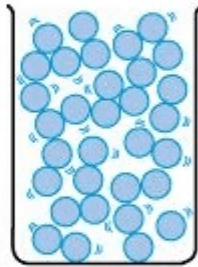
Gas

Hydrogen: 0.089 kg/m³
Oxygen: 1.43 kg/m³
Carbon Dioxide: 1.96 kg/m³



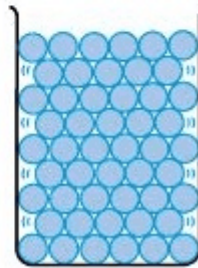
Liquid

Alcohol: 789 kg/m³
Water: 1000 kg/m³
Mercury: 13534 kg/m³



Solid

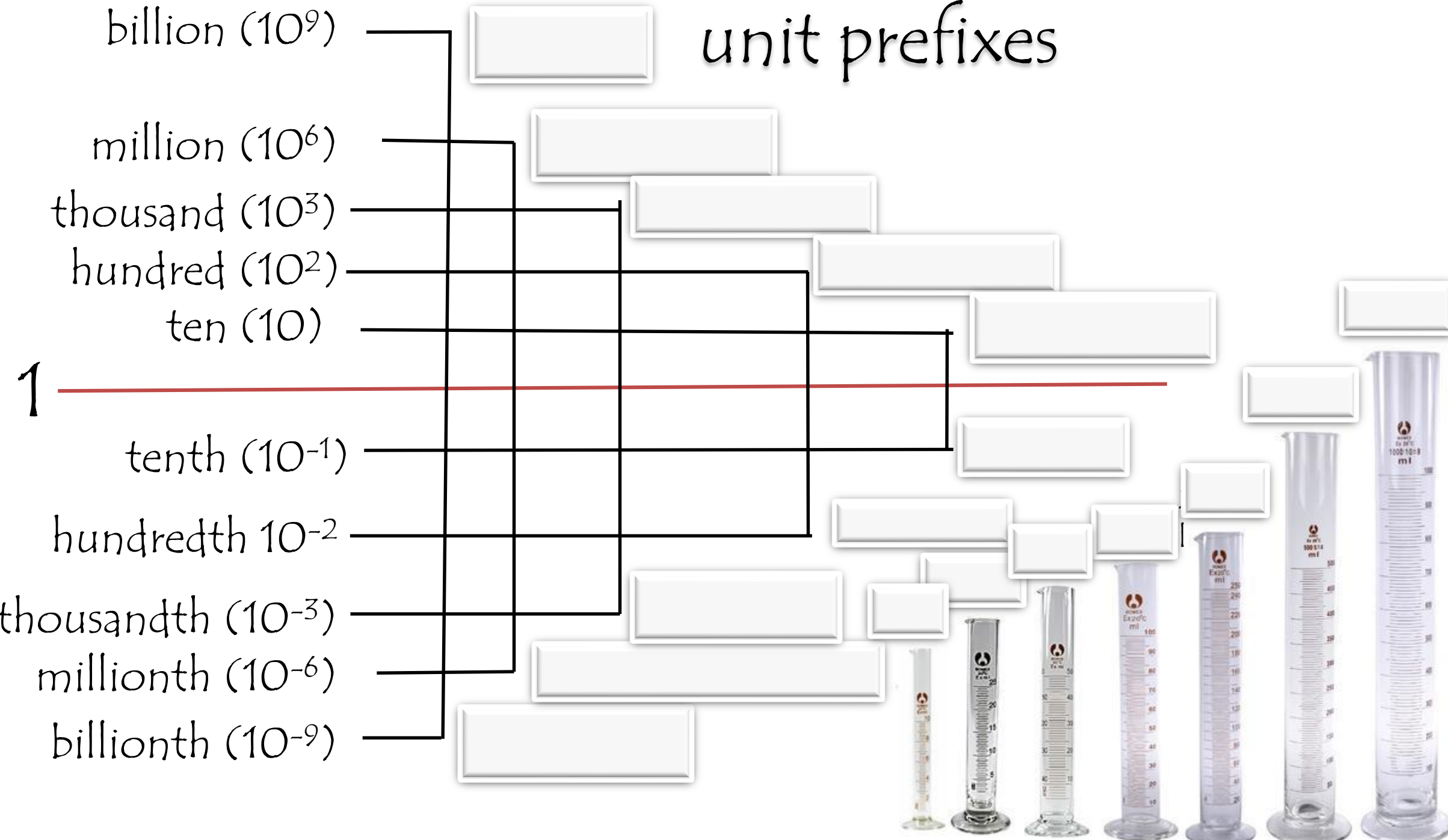
Aluminium: 2700 kg/m³
Steel: 7500 kg/m³
Uranium: 18800 kg/m³



13.5 g of aluminum has a volume of 5.0 mL. Density?

what is the mass of 2 mL of aluminum?

unit prefixes



temperature



S.I. unit: Kelvin....why?

K to °C:

$$K = ^\circ C + 273.15$$

25°C = ?K

°F to °C:

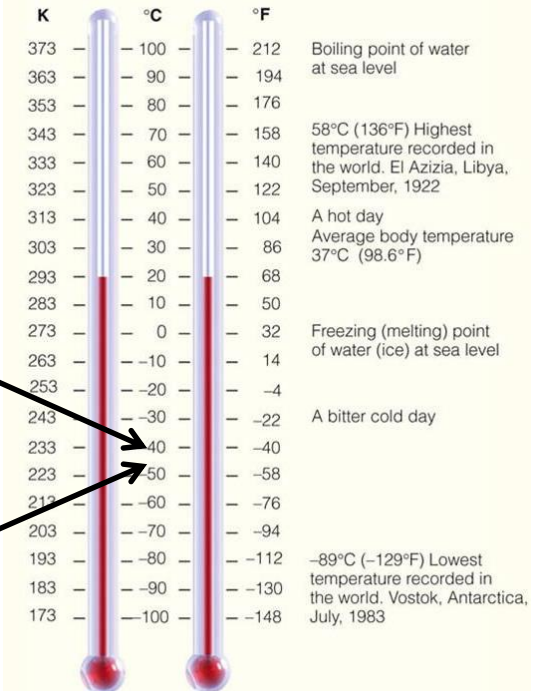
$$^\circ C = (^\circ F - 32) \times 5/9$$

$$^\circ F = ^\circ C \times 9/5 + 32$$

°F to °C	Deduct 32, then multiply by 5, then divide by 9
°C to °F	Multiply by 9, then divide by 5, then add 32

-40°C = ?°F

-40°F = ?°C



scientific notation

for big and small numbers

draw a line to make it between 1 and 10; count to decimal point.

always 1-10 always 10^x

10,000

212 .0097

602,000,000,000,000,000,000,000

$= -2.86 \times 10^3$ $= 9.742 \times 10^{-4}$

entering scientific data on your calculators:
use the E button: $3 \times 10^8 = 3E8$



may be E, e, ee, exp; often requires 2nd button (yuck)

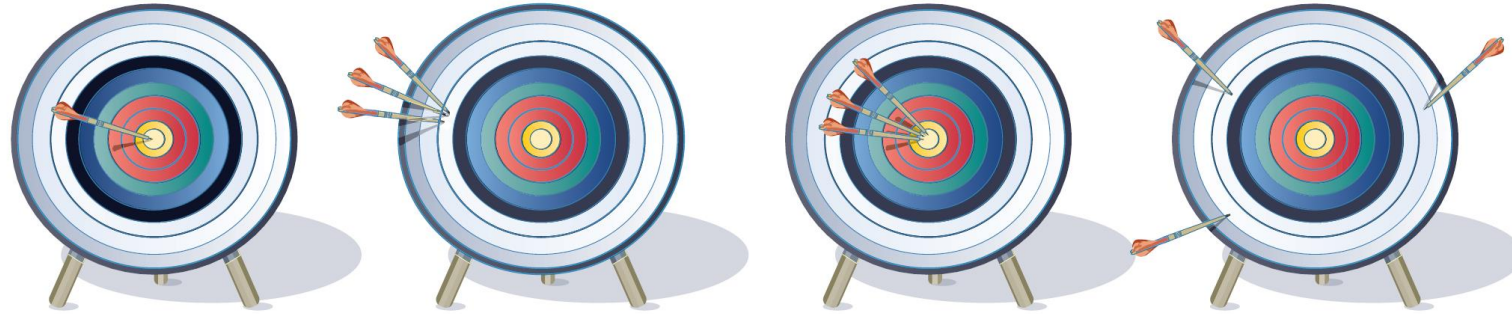
how do you enter 6.02×10^{23} ?

find change sign button (+/-) $(3 \times 10^{-2}) \times (-4.2 \times 10^{-4}) = ?$

translate: $3E-0.42$

$(2 \times 10^1)(1 \times 10^1) = ?$

accurate, precise, or both?



Four empty rounded rectangular boxes for labeling the targets.

ok...but why are they used interchangeably so often??

accuracy: The quality, of being correct or precise.

precision: The quality, condition, or fact of being exact and accurate.

:

qualitative or quantitative?

several arrows

3 arrows

A large empty rounded rectangular box for additional notes or a summary.

unit conversions

1. start with what you are given

2. estimate steps and write the final units

3. multiply using conversion factors

4. cancel your units.

a. 7.25 dollars = _____ quarters

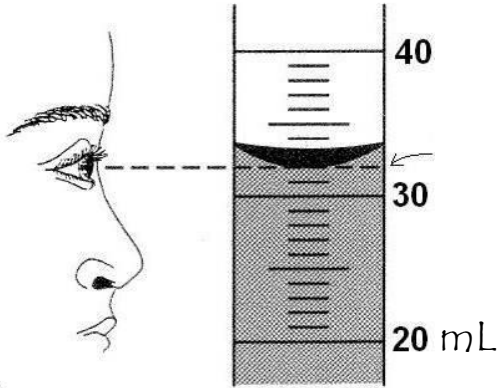
b. 1,285 quarters = _____ dollars

c. 65 miles/hour = _____ meters/second (1609 meters = 1 mile; 3600 seconds = 1 hour)

d. Most gases occupy 24 liters per mole at room temperature. Given that carbon dioxide has a molar mass of 44 grams per mole, what is the density of carbon dioxide at room temperature in grams per liter?

significant figures

volume?



number

sig. figs (sf). why

32

0.0323

3.004

300

300.

300.20

rounding: ex: 2.25 to 2 sf:

+,- ex: 4.16+ 3.3 =

x, / ex: 666 /333 =

infinite sig. figs.

round as you go?

how many extra digits should I carry along?

combinations?

ex: (3.111 + 5.03) x 33 =

when measuring:

why is it important to line up level to the meniscus?

how does this device minimize parallax??



how many significant figures??

.030690

percent accuracy and percent error

you measure your mass to be 120 lbs,
but in reality it is 150 lbs. What is your percent error?

5 states of matter

hot



cold



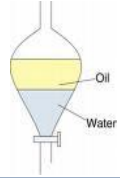
state?

fill bottom of
container
perfectly?

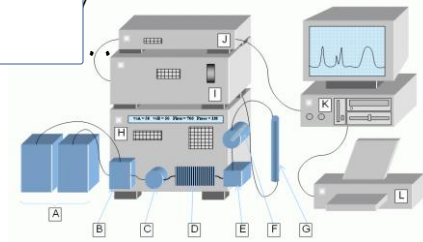
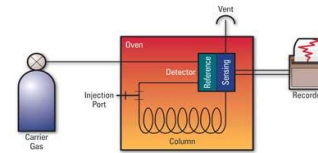
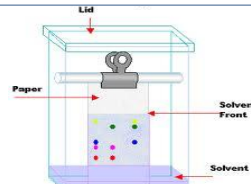
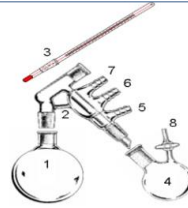
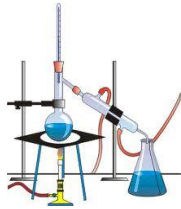
fills all of
container?

compressible?

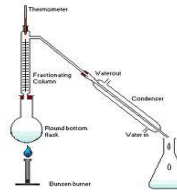
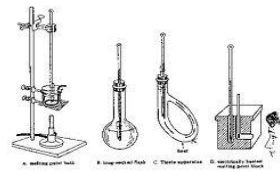
purification methods



still in use



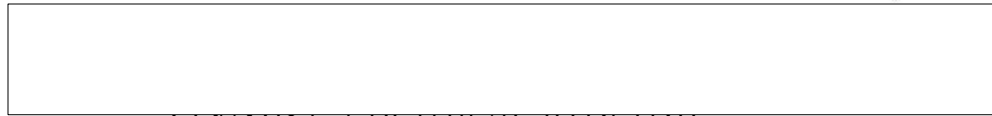
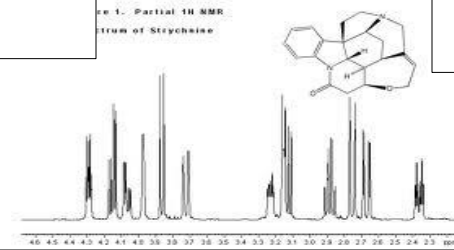
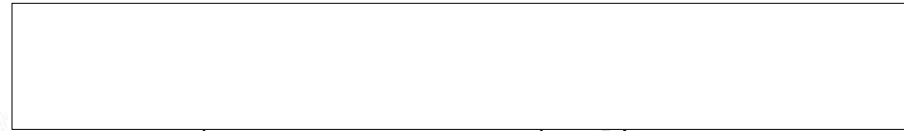
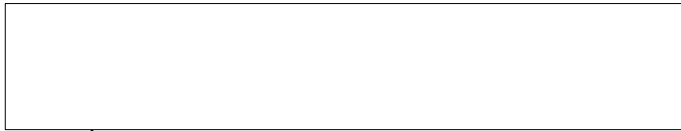
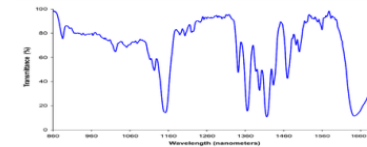
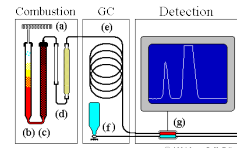
classical identification methods



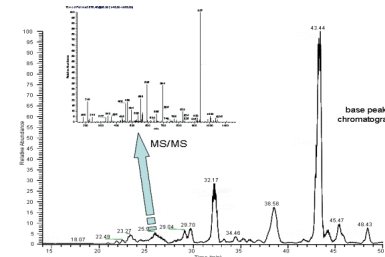
still in use



modern identification methods (L1, honors only)



(NMR): chemical structure



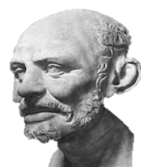
a brief history of **the atom**

early ideas

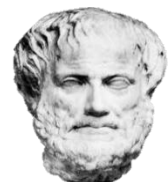
symbol

inventor

idea, source



400 BC



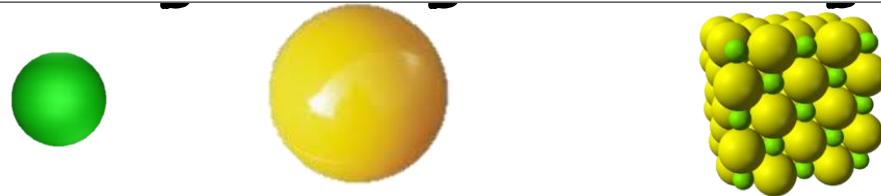
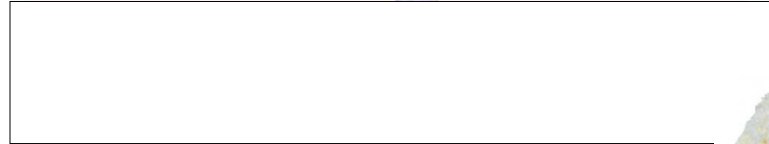
400 BC



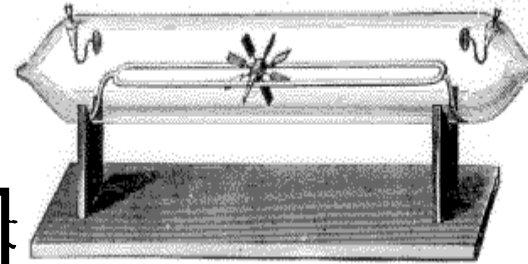
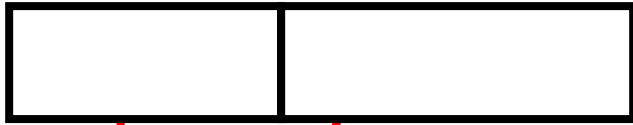
1000 AD

their evidence:

early evidence for the atom



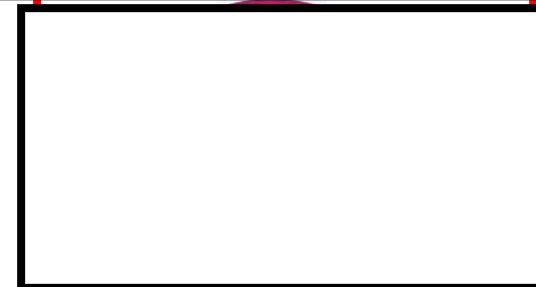
thomson's 1897 cathode ray tube experiment:



proposes:

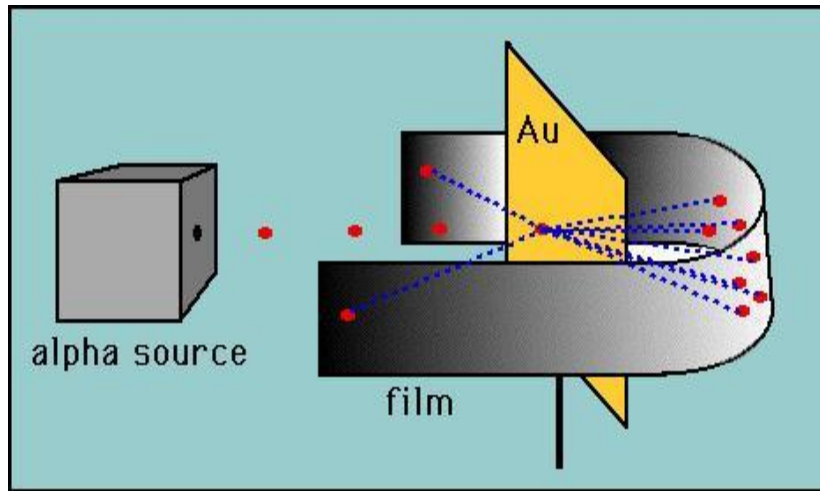


thomson



where are the electrons?

Rutherford's 1907 gold foil experiment



conclusion:

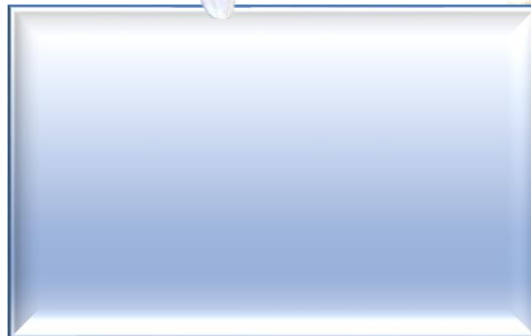
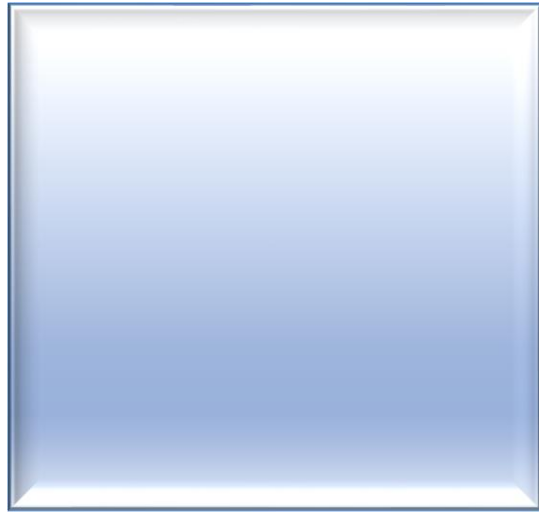
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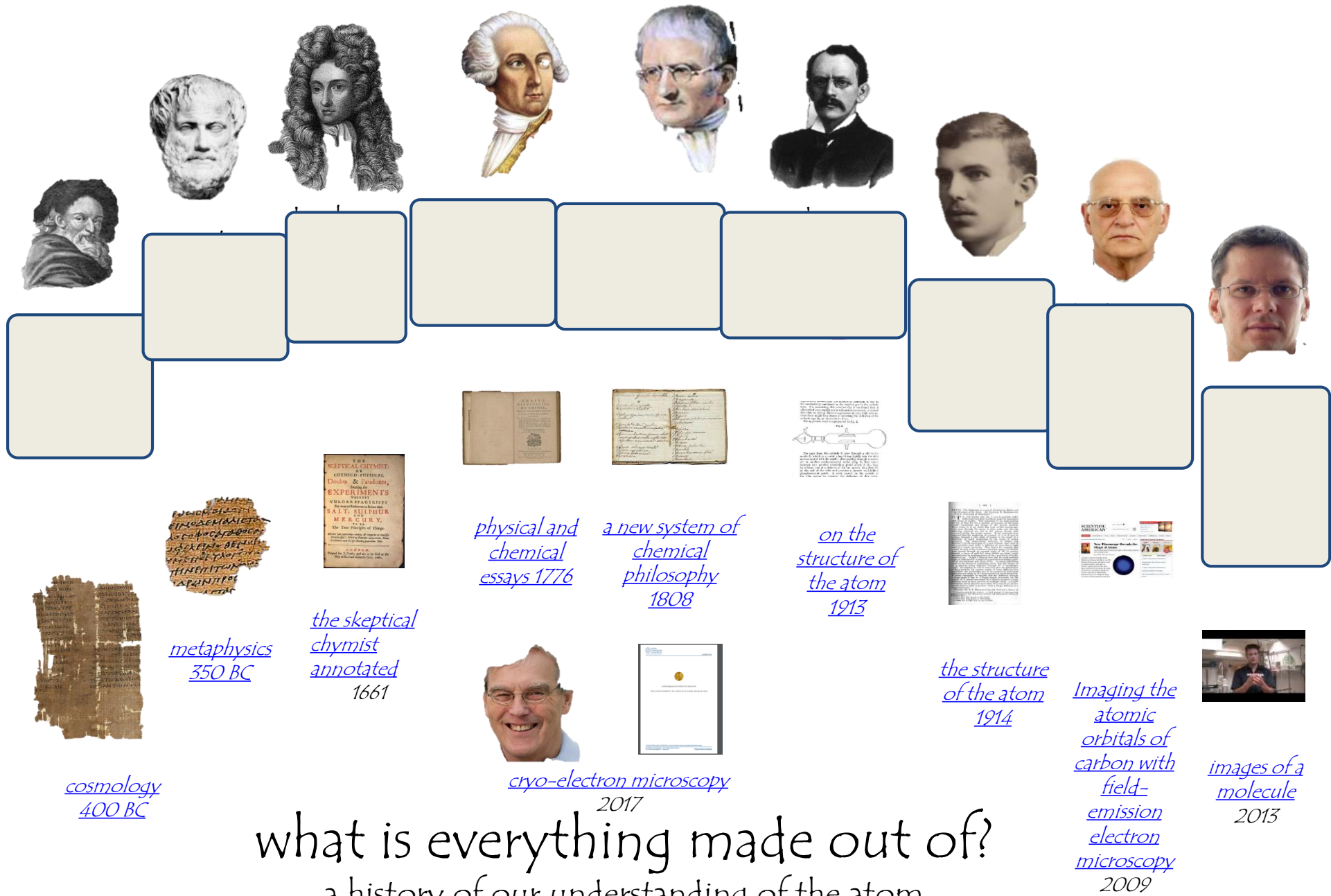
Rutherford

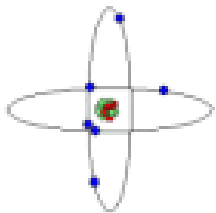


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history of the atom







atomic bookkeeping: p^+ , n^0 , and e^-

term		
atomic #		
mass #		
isotope		
ion		
cation		
anion		
average atomic mass		
band of stability		

F^- and Neon both have 10 electrons: They are .

determination of average atomic mass

solve this problem

element X has 2 isotopes:

isotope a

10 protons,

10 neutrons

abundance: 40%

isotope b

10 protons

11 neutrons

abundance: 60%

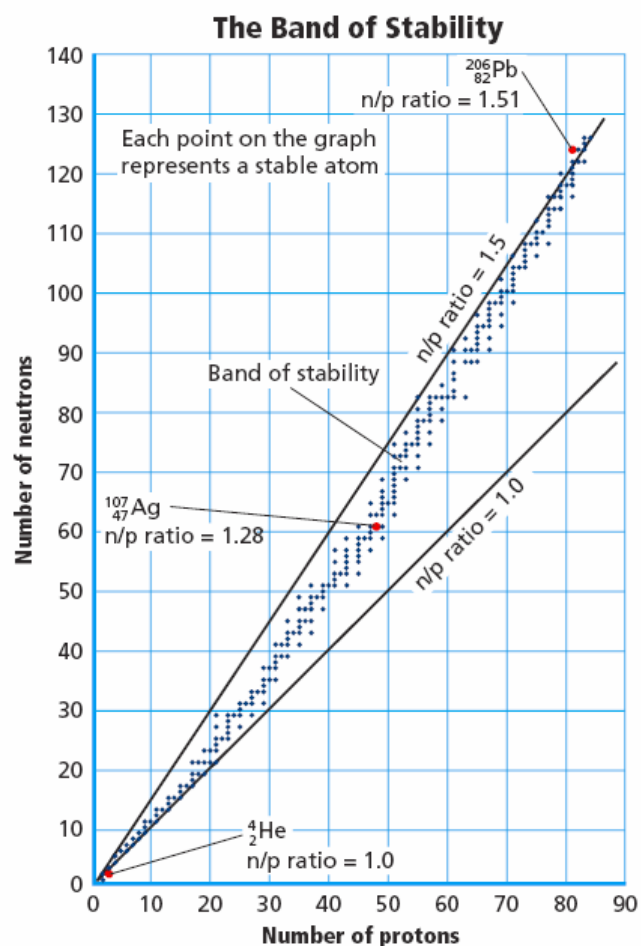


what is the average atomic mass of element X?



average atomic mass calculation consider the hypothetical element binkowskium (Bn)

P	N	abundance	average atomic mass?
15	15	66%	<input type="text"/>
15	17	34%	

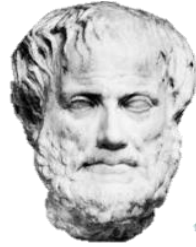


how many neutrons is too many?:
how to predict the scary elements

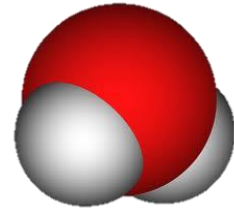
the "band of stability"



what is everything made out of?



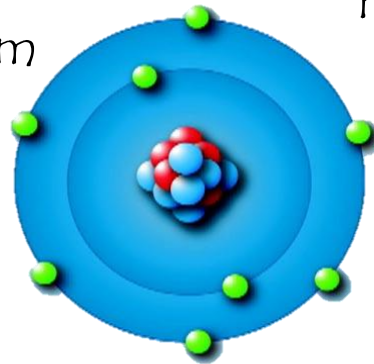
matter
substance



molecule

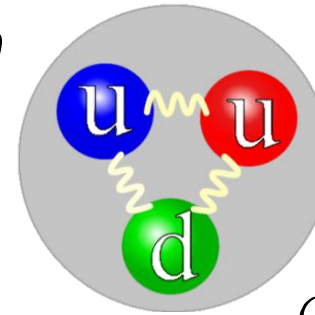


atom



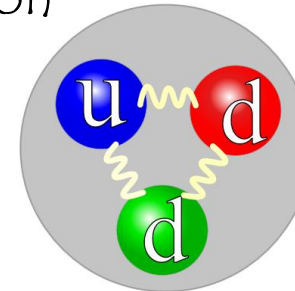
P, N, and E

proton



u: up quarks
d: down quarks
g: gluons

neutron

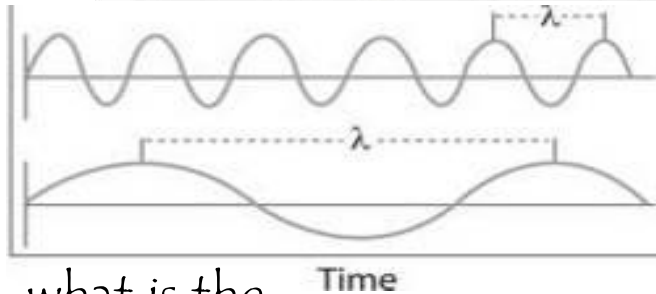
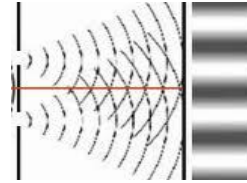
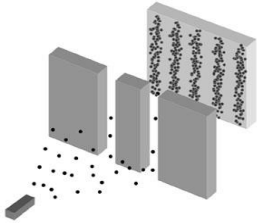
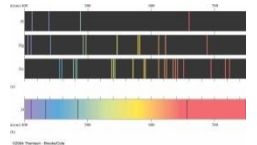


electron

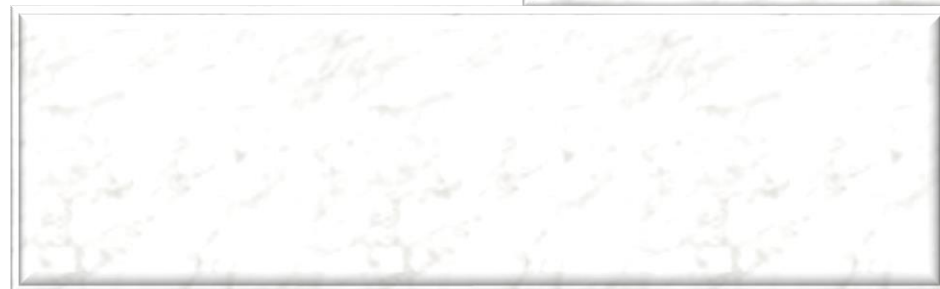
introduction to the electron light?



observation: light passing through
2 slits can create multiple lines.: how can this be?
this is **superposition**



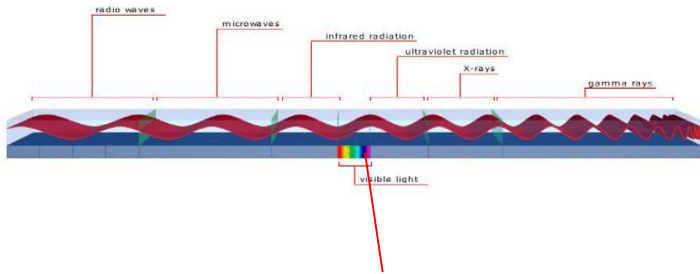
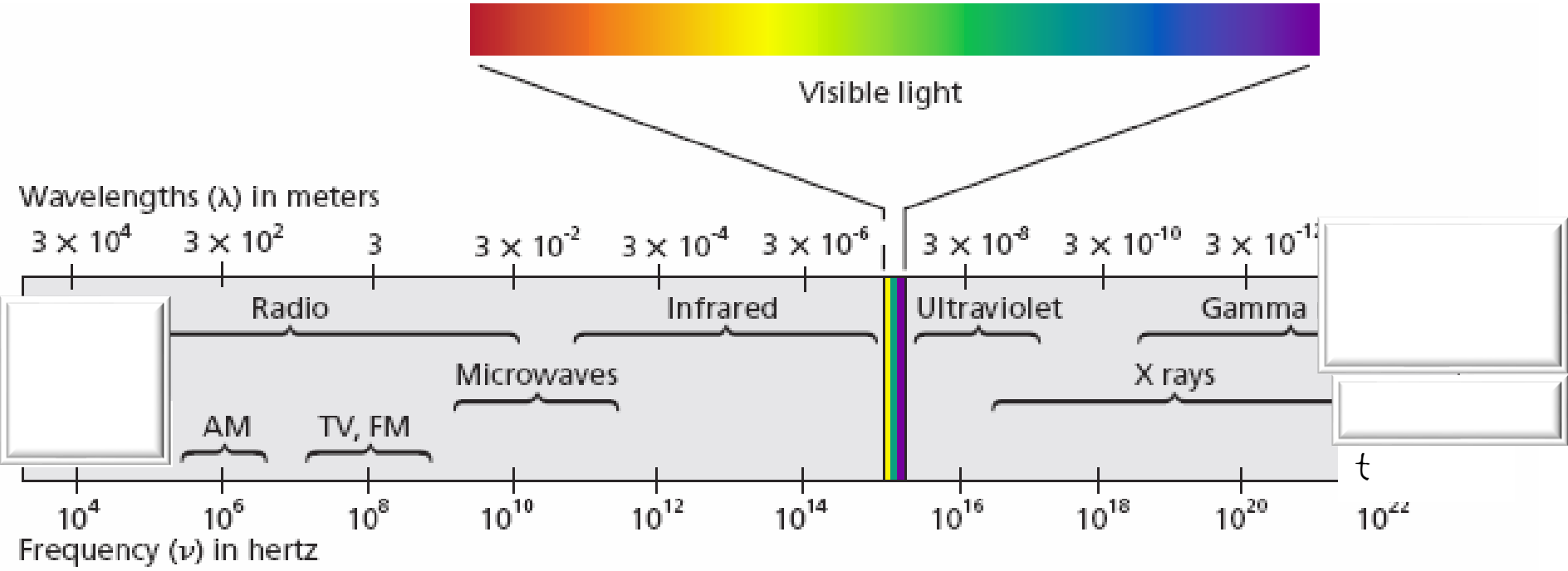
what is the
wavelength of
violet light in
nanometers; f
 $= 7.23 \times 10^{14} \text{ s}^{-1}$
?



What is the frequency
of green light, which
has a wavelength of
 $4.90 \times 10^{-7} \text{ m}$?



the electromagnetic spectrum
so much you don't see



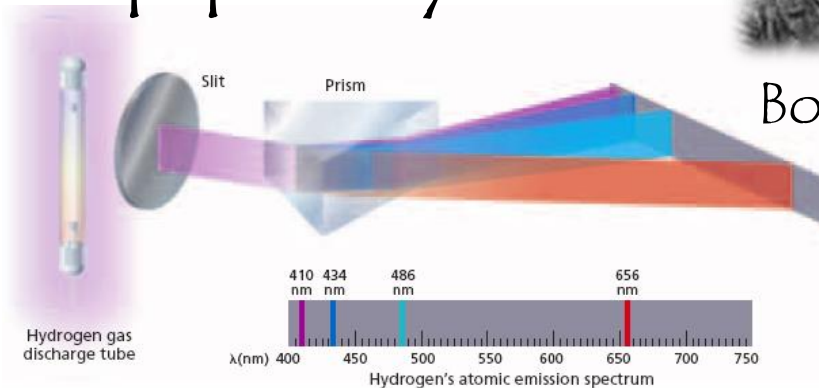
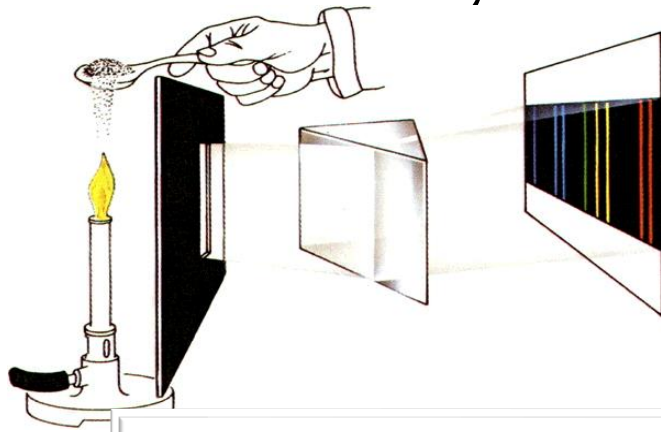
656 nm

where are the electrons?:

the story of bohr's epiphany



Bohr



$\lambda_{nm} = 656, 486, 434, 410 \dots$ what number is next??



Balmer

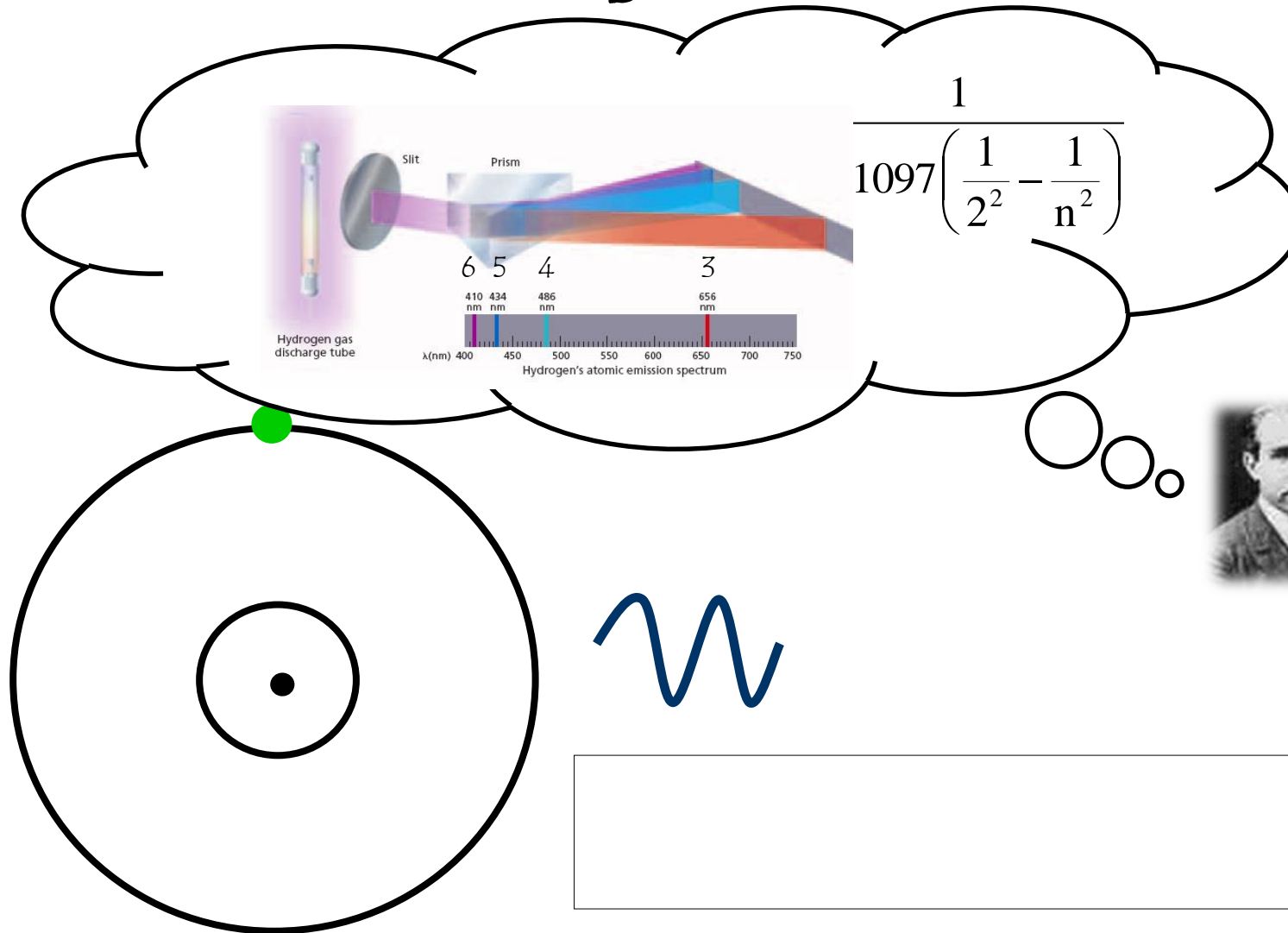
Try it for 3 \rightarrow 2

outer inner

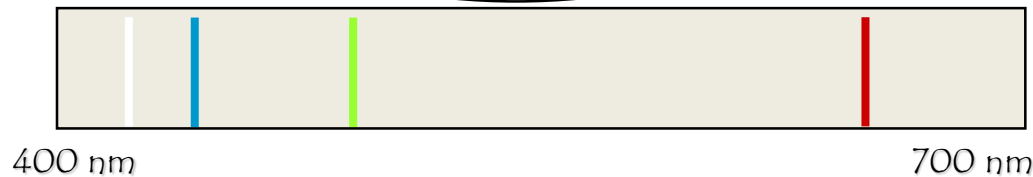
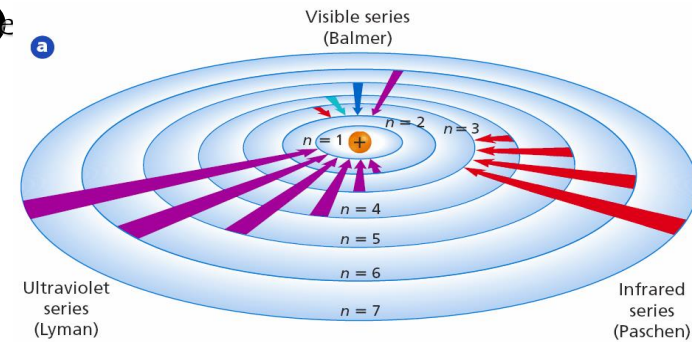
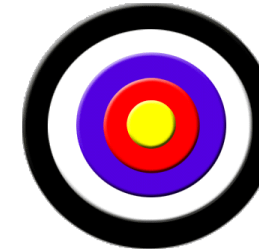
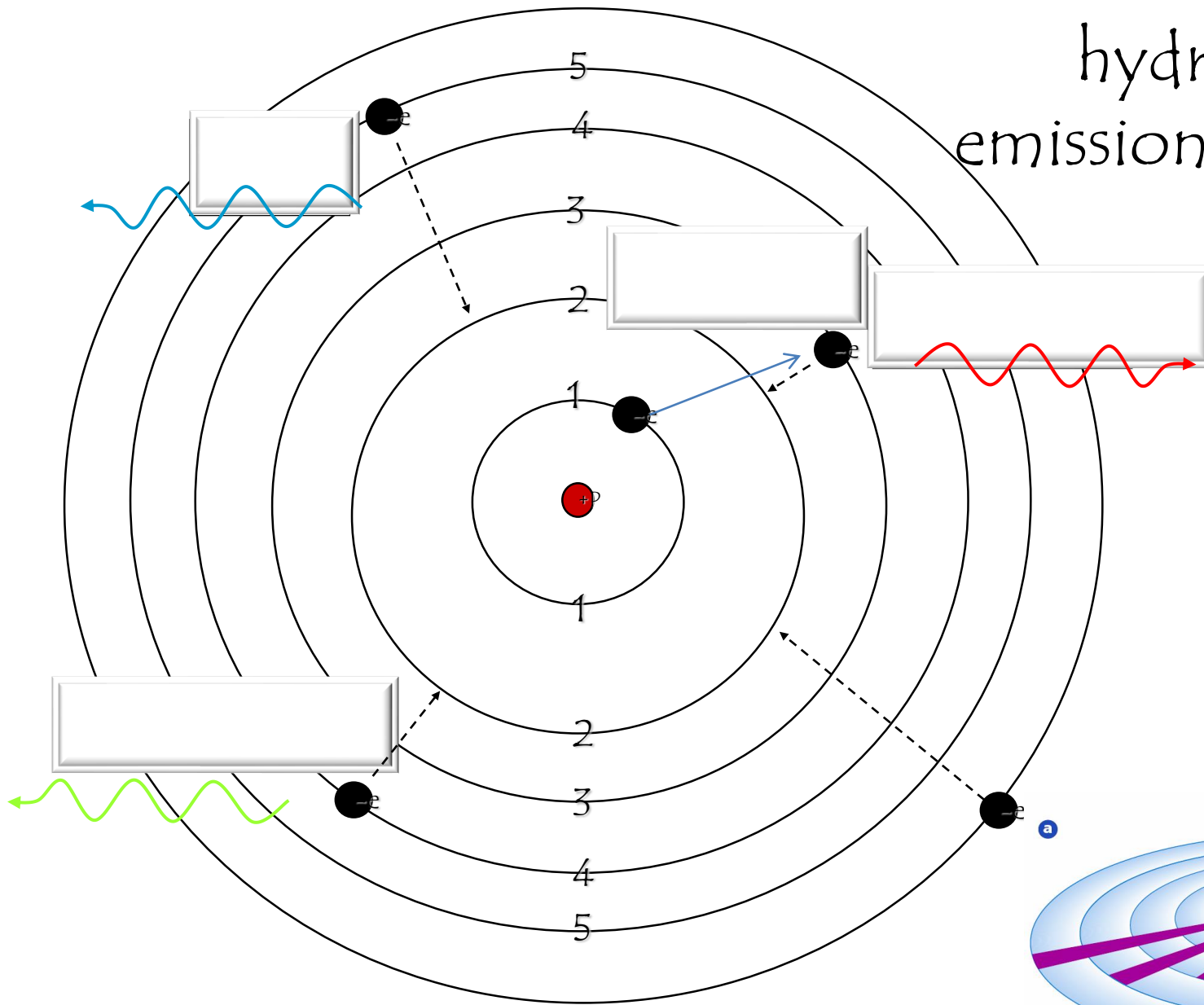


Rydberg

Bohr sees the connection between light and the electron



hydrogen emission: it all fits



energy of hydrogen photon emission

Planck found the energy of a photon is proportional to its frequency:

where his Planck's constant

frequency is related to wavelength

where s is the speed of light

so hydrogen photon energy can be re-expressed by wavelength

and since the wavelength of hydrogen electron emission is known:

the energy of hydrogen photon emission can be calculated directly:



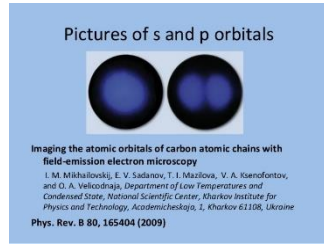
atomic orbital theory (to argon)

atomic orbitals:
 "subshells" of paired electrons
 paired electrons = orbital

electron configuration

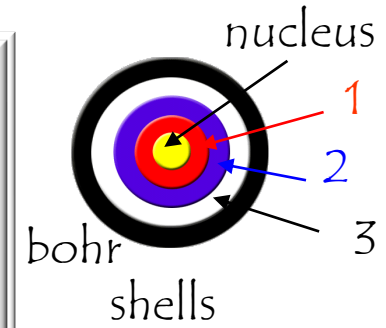


igor mikhailovskij

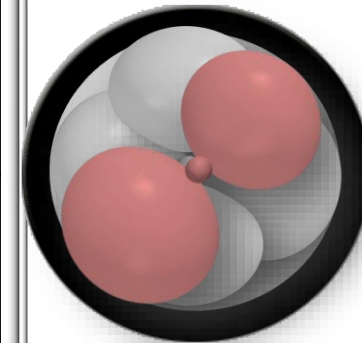


electrons
 shell total

shell	# electrons total	level	orbital	# e's



after: schrodinger,
 mikhailovskij, others



orbitals

aufbau order is a powerful tool

$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^6 6s^2 4f^{14} 5d^{10} 6p^6 7s^2 5f^{14} 6d^{10} \dots$

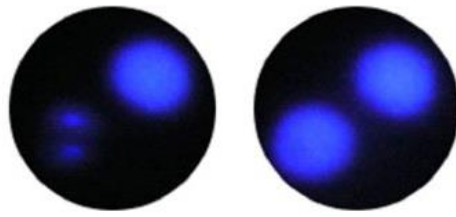
The periodic table is annotated with valence electron counts and group labels. Key features include:

- Group 1:** Alkali metals, labeled with a blue '+1' and '1 valence electron'.
- Group 2:** Alkaline earth metals, labeled with a blue '+2' and '2 valence electrons'.
- Transition Metals (Groups 3-10):** Labeled with 'Transition metals: 2 valence electrons'.
- Group 11:** Labeled with '+1'.
- Group 12:** Labeled with '+2'.
- Groups 13-17:** Labeled with valence electron counts: 3, 4, 5, 6, 7, and -1 (halogens).
- Group 18:** Noble gases, labeled with '0'.

Red boxes highlight the following elements: B, C, N, O, Al, Si, P, S, Ga, Ge, As, Se, Br, Kr, In, Sn, Sb, Te, I, Xe, Tl, Pb, Bi, Po, At, Rn, Uut, Uuq, Uup, Uuh, Uus, Uuo.

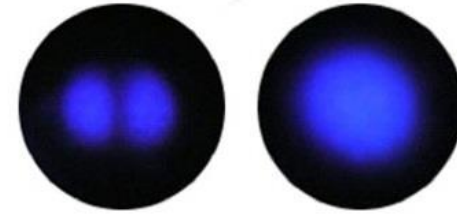
A legend in the bottom right corner defines the color coding for element states: Solid (yellow), Liquid (light blue), Gas (light green), and Manmade (light purple).

conclusion:



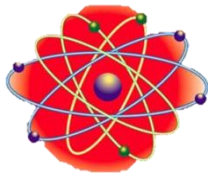
electrons

aufbau order is infinite



1 s ²									
	2 s ²								
2 p ⁶		3 s ²							
	3 p ⁶		4 s ²						
3 d ¹⁰		4 p ⁶		5 s ²					
	4 d ¹⁰		5 p ⁶		6 s ²				
4 f ¹⁴		5 d ¹⁰		6 p ⁶		7 s ²			
	5 f ¹⁴		6 d ¹⁰		7 p ⁶		8 s ²		
5 g ¹⁸		6 f ¹⁴		7 d ¹⁰		8 p ⁶		9 s ²	
	6 d ¹⁸		7 f ¹⁴		8 d ¹⁰		9 p ⁶		10 s ²

1s² 2s² 2p⁶ 3s² 3p⁶ 4s² 3d¹⁰ 4p⁶ 5s² 4d¹⁰ 5p⁶ 6s² 4f¹⁴ 5d¹⁰ 6p⁶ 7s² 5f¹⁴ 6d¹⁰...



electron configuration with orbital notation

tells us where the electrons are in an atom in great detail

${}_{3}\text{Li}:$ ← Pauli Principle:

try it for carbon: ${}_{6}\text{C}:$ please give the electron configuration with orbital notation for sulfur ${}_{16}\text{S}:$

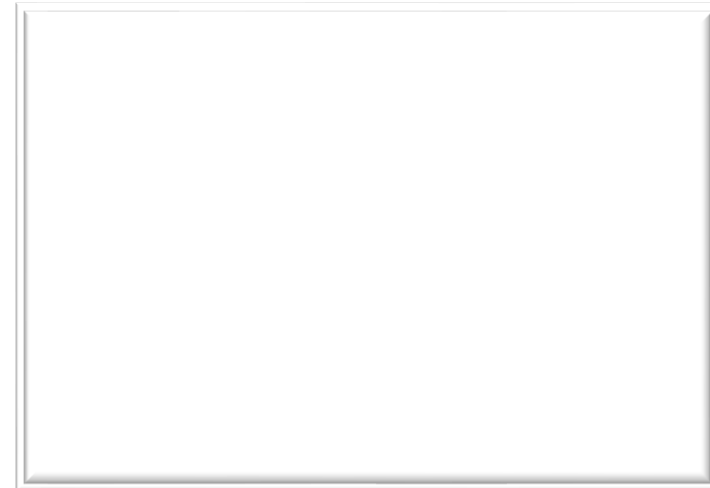
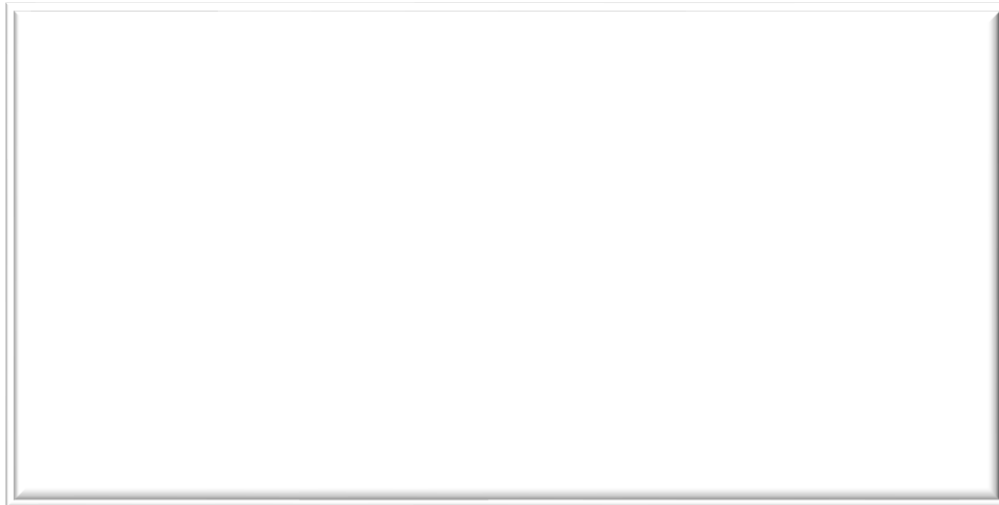
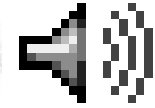
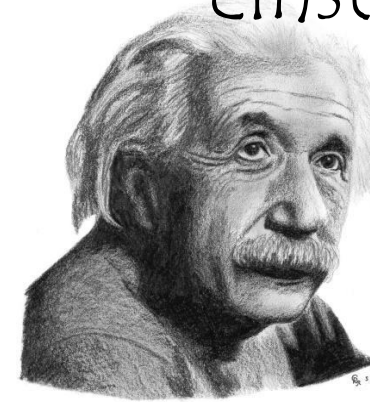
hunds rule: electrons spread out within orbital groups

heisenberg's uncertainty proposal

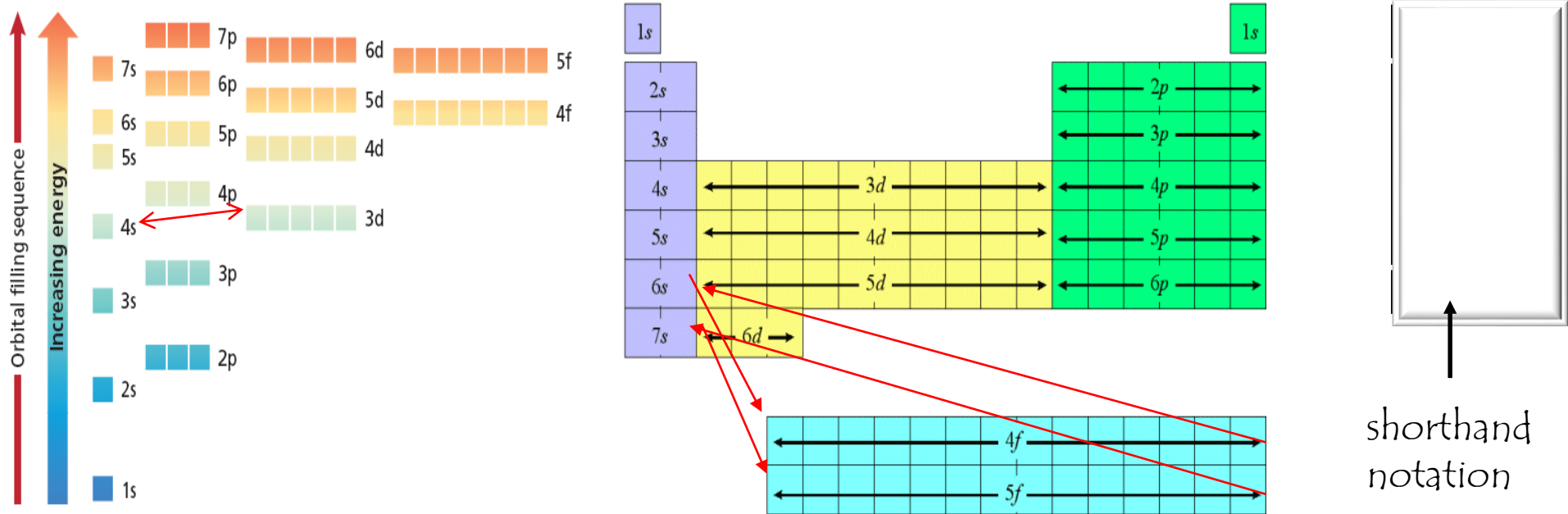
heisenberg:



einstein:



aufbau order; shorthand notation

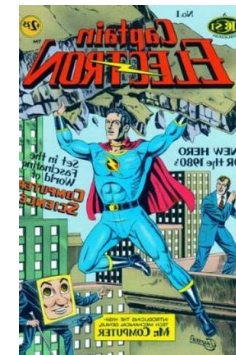
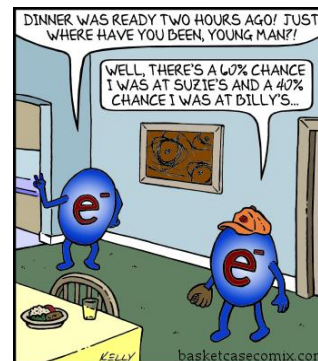
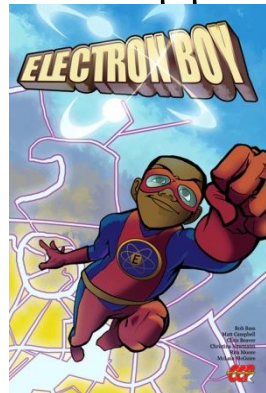


${}_{12}\text{Mg}$:

${}_{21}\text{Sc}$:

principles and rules of electron configuration

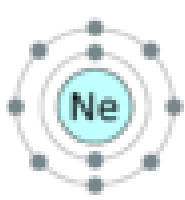
principle or rule	bad	good
heisenberg (e-position uncertain)		
aufbau (build up)		
hund's rule (spread out)		
pauli (opp. spins)		



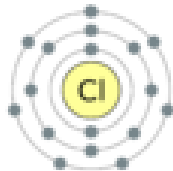
it's all about the valence electrons

the big idea:

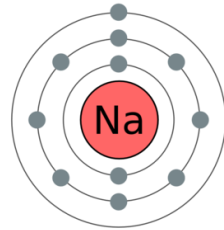
atoms want full outer shells.
(almost always 8 electrons)



neon:
stable 😊



chlorine
unstable:
will gain
one...



sodium:
unstable:
will lose 1

...or share

(outer shell)

lose 1

lose 2

1 valence electron
+1
Alkali metals
Group 1

2 valence electrons
+2
Alkaline earth metals
Group 2

1s	1 H hydrogen 1.01	2 He helium 4.00
2s	3 Li lithium 6.94	4 Be beryllium 9.01
3s	11 Na sodium 22.99	12 Mg magnesium 24.31
4s	19 K potassium 39.10	20 Ca calcium 40.08
5s	37 Rb rubidium 85.47	38 Sr strontium 87.62
6s	55 Cs cesium 132.91	56 Ba barium 137.33
7s	87 Fr francium 223.02	88 Ra radium 226.02

4f	57 La lanthanum 138.91	58 Ce cerium 140.12	59 Pr praseodymium 140.91	60 Nd neodymium 144.24	61 Pm promethium 144.91	62 Sm samarium 150.41	63 Eu europium 151.96	64 Gd gadolinium 157.25	65 Tb terbium 158.92	66 Dy dysprosium 162.50	67 Ho holmium 164.93	68 Er erbium 167.26	69 Tm thulium 168.93	70 Yb ytterbium 173.04
5f	89 Ac actinium 227.03	90 Th thorium 232.04	91 Pa protactinium 231.04	92 U uranium 238.03	93 Np neptunium 237.05	94 Pu plutonium 244.06	95 Am americium 243.06	96 Cm curium (247)	97 Bk berkelium (249)	98 Cf californium (251)	99 Es einsteinium (254)	100 Fm fermium 257.10	101 Md mendelevium (256)	102 No nobelium (254)

lose....
complex: unfilled inner shells

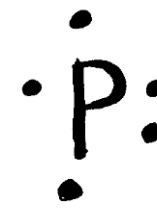
Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Group 9	Group 10	Group 11	Group 12
21 Sc scandium 44.96	22 Ti titanium 47.90	23 V vanadium 50.94	24 Cr chromium 52.00	25 Mn manganese 54.94	26 Fe iron 55.85	27 Co cobalt 58.93	28 Ni nickel 58.71	29 Cu copper 63.55	30 Zn zinc 65.37
39 Y yttrium 88.91	40 Zr zirconium 91.22	41 Nb niobium 92.91	42 Mo molybdenum 95.94	43 Tc technetium 98.91	44 Ru ruthenium 101.07	45 Rh rhodium 102.91	46 Pd palladium 106.40	47 Ag silver 107.87	48 Cd cadmium 112.40
71 Lu lutetium 174.97	72 Hf hafnium 178.49	73 Ta tantalum 180.95	74 W tungsten 183.85	75 Re rhenium 186.21	76 Os osmium 190.20	77 Ir iridium 192.22	78 Pt platinum 195.09	79 Au gold 196.97	80 Hg mercury 200.59
103 Lr lawrencium 262.11	104 Rf rutherfordium 261.11	105 Db dubnium 262.11	106 Sg seaborgium 263.12	107 Bh bohrium 264.12	108 Hs hassium 265.13	109 Mt meitnerium (268)	110 Ds darmstadtium (281)	111 Rg roentgenium (272)	112 Uub ununbium (285)

...or share
lose 4
or gain 4
lose 3
gain 3
gain 2
gain 1
stable
0
Noble gases
Group 18

3	4	5	6	7	8	9	10
5 B boron 10.81	6 C carbon 12.01	7 N nitrogen 14.01	8 O oxygen 16.00	9 F fluorine 19.00	10 Ne neon 20.18	11 Na sodium 22.99	12 Mg magnesium 24.31
13 Al aluminum 26.98	14 Si silicon 28.09	15 P phosphorus 30.97	16 S sulfur 32.07	17 Cl chlorine 35.45	18 Ar argon 39.95	19 K potassium 39.10	20 Ca calcium 40.08
31 Ga gallium 69.72	32 Ge germanium 72.59	33 As arsenic 74.92	34 Se selenium 78.96	35 Br bromine 79.91	36 Kr krypton 83.80	37 Rb rubidium 85.47	38 Sr strontium 87.62
49 In indium 114.82	50 Sn tin 118.69	51 Sb antimony 121.75	52 Te tellurium 127.60	53 I iodine 126.90	54 Xe xenon 131.30	55 Cs cesium 132.91	56 Ba barium 137.33
81 Tl thallium 204.37	82 Pb lead 207.19	83 Bi bismuth 208.98	84 Po polonium (210)	85 At astatine (210)	86 Rn radon (220)	87 Fr francium 223.02	88 Ra radium 226.02
113 Uut ununtrium (284)	114 Uuq ununquadium (289)	115 Uup ununpentium (288)	116 Uuh ununhexium (289)	117 Uus ununseptium (295)	118 Uuo ununoctium (293)	119 Uu ununennium (288)	120 Uu ununnium (289)

21 Sc scandium 44.96	22 Ti titanium 47.90	23 V vanadium 50.94	24 Cr chromium 52.00	25 Mn manganese 54.94	26 Fe iron 55.85	27 Co cobalt 58.93	28 Ni nickel 58.71	29 Cu copper 63.55	30 Zn zinc 65.37
----------------------------	----------------------------	---------------------------	----------------------------	-----------------------------	------------------------	--------------------------	--------------------------	--------------------------	------------------------

electron dot structures: a quick look at valence electrons



--	--	--	--

no...always spread
out valence electrons

try H,O,N,C

--	--	--	--

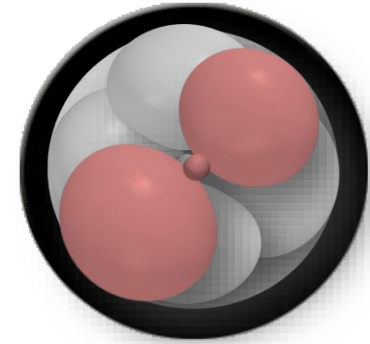
valence electrons are the key to
understanding:

--

fortunately, it is nicely categorized in our next topic:

--

The electron: fact sheet



exists

- is located:
- Outside the nucleus
- In shells
- In subshells (s p d f)
- In orbitals
- With opposite spins

is an elementary particle.

doesn't have much mass (10^{-28} g; 1836x lighter than a proton)

what is the world made out of?

the development of the periodic table

9000
BC

1790

1810

March 6
1869

1929

2011

device



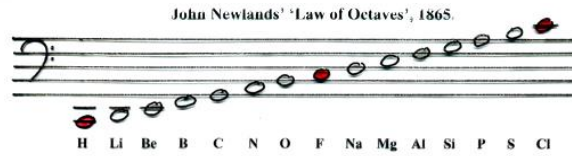
fire



quantitative
instrumentatio
n



Volta's pile



John Newlands' 'Law of Octaves', 1865.

Newland's law of octaves



1st particle
accelerator



large hadron
collider

contributors



cavemen



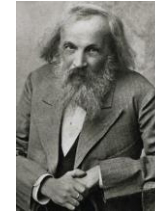
Lavoisier



Volta



Newlands



Mendeleev
famous lecture 1869



Seaborg



Stark
(just kidding)

results



ancient copper
9000 BC



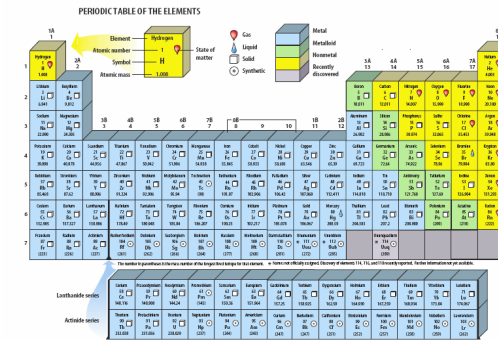
ancient lead



early elemental

Group	I	II	III	IV	V	VI	VII	VIII
Period 1	H=1							
2	Li=7	Be=9.4	B=11	C=12	N=14	O=16	F=19	
3	Na=23	Mg=24	Al=27.3	Si=28	P=31	S=32	Cl=35.5	
4	K=39	Ca=40	?=44	Ti=48	V=51	Cr=52	Mn=55	Fe=56, Co=59 Ni=59
5	Cu=63	Zn=65	?=68	?=72	As=75	Se=78	Br=80	
6	Rb=85	Sr=87	?Yt=88	Zr=90	Nb=94	Mo=96	?=100	Ru=104, Rh=104 Pd=106
7	Ag=108	Cd=112	In=113	Sn=118	Sb=122	Te=125	J=127	
8	Cs=133	Ba=137	?Di=138	?Ce=140				
9								
10			?Er=178	?La=180	Ta=182	W=184		Os=195, Ir=197 Pt=198
11	Au=199	Hg=200	Tl=204	Pb=207	Bi=208			
12				Th=231		U=240		

by the 1860's, elements were being
predicted based on properties of



modern periodic table

summary

--	--	--	--

organization of the periodic table

it's about the electrons:

valence electrons: charge orbitals blocks periods groups or families: alkali metals



1 valence electron
+1
Alkali metals
Group 1

2 valence electrons
+2
Alkaline earth metals
Group 2

alkaline earth metals halogens noble gases



metals: nonmetals metalloids



1s	1 H hydrogen 1.01 <small>(H is a nonmetal)</small>
2s	3 Li lithium 6.94
	4 Be beryllium 9.01
3s	11 Na sodium 22.99
	12 Mg magnesium 24.31
4s	19 K potassium 39.10
	20 Ca calcium 40.08
5s	37 Rb rubidium 85.47
	38 Sr strontium 87.62
6s	55 Cs cesium 132.91
	56 Ba barium 137.33
7s	87 Fr francium 223.02
	88 Ra radium 226.02

Transition metals: 2 valence electrons multiple charges

Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Group 9	Group 10	Group 11	Group 12
21 Sc scandium 44.96	22 Ti titanium 47.90	23 V vanadium 50.94	24 Cr chromium 52.00	25 Mn manganese 54.94	26 Fe iron 55.85	27 Co cobalt 58.93	28 Ni nickel 58.71	29 Cu copper 63.55	30 Zn zinc 65.37
39 Y yttrium 88.91	40 Zr zirconium 91.22	41 Nb niobium 92.91	42 Mo molybdenum 95.94	43 Tc technetium 98.91	44 Ru ruthenium 101.07	45 Rh rhodium 102.91	46 Pd palladium 106.40	47 Ag silver 107.87	48 Cd cadmium 112.40
71 Lu lutetium 174.97	72 Hf hafnium 178.49	73 Ta tantalum 180.95	74 W tungsten 183.85	75 Re rhenium 186.21	76 Os osmium 190.20	77 Ir iridium 192.22	78 Pt platinum 195.09	79 Au gold 196.97	80 Hg mercury 200.59
103 Lr lawrencium 262.11	104 Rf rutherfordium 261.11	105 Db dubnium 262.11	106 Sg seaborgium 263.12	107 Bh bohrium 264.12	108 Hs hassium 265.13	109 Mt meitnerium (268)	110 Ds darmstadtium (281)	111 Rg roentgenium (272)	112 Uub ununbium (285)

Valence electrons:

3 nonmetal	4	5	6	7	8 Noble gases Group 18
+3	+4, -4	-3	-2	-1 halogens	0
Group 13	Group 14	Group 15	Group 16	Group 17	Group 18
5 B boron 10.81	6 C carbon 12.01	7 N nitrogen 14.01	8 O oxygen 16.00	9 F fluorine 19.00	10 Ne neon 20.18
13 Al aluminum 26.98	14 Si silicon 28.09	15 P phosphorus 30.97	16 S sulfur 32.07	17 Cl chlorine 35.45	18 Ar argon 39.95
31 Ga gallium 69.72	32 Ge germanium 72.59	33 As arsenic 74.9	34 Se selenium 78.96	35 Br bromine 79.91	36 Kr krypton 83.80
49 In indium 114.82	50 Sn tin 118.69	51 Sb antimony 121.75	52 Te tellurium 127.60	53 I iodine 126.90	54 Xe xenon 131.30
81 Tl thallium 204.37	82 Pb lead 207.19	83 Bi bismuth 208.98	84 Po polonium (210)	85 At astatine (210)	86 Rn radon (220)
113 Uut ununtrium (284)	114 Uuq ununquadium (289)	115 Uup ununpentium (288)	116 Uuh ununhexium (289)	117 Uus ununseptium (295)	118 Uuo ununoctium (295)

4f	57 La lanthanum 138.91	58 Ce cerium 140.12	59 Pr praseodymium 140.91	60 Nd neodymium 144.24	61 Pm promethium 144.91	62 Sm samarium 150.41	63 Eu europium 151.96	64 Gd gadolinium 157.25	65 Tb terbium 158.92	66 Dy dysprosium 162.50	67 Ho holmium 164.93	68 Er erbium 167.26	69 Tm thulium 168.93	70 Yb ytterbium 173.04
5f	89 Ac actinium 227.03	90 Th thorium 232.04	91 Pa protactinium 231.04	92 U uranium 238.03	93 Np neptunium 237.05	94 Pu plutonium 244.06	95 Am americium 243.06	96 Cm curium (247)	97 Bk berkelium (249)	98 Cf californium (251)	99 Es einsteinium (254)	100 Fm fermium 257.10	101 Md mendelevium (256)	102 No nobelium (254)

to 71

to 103

Atomic number

Symbol: Solid, Liquid, Gas, Manmade

name

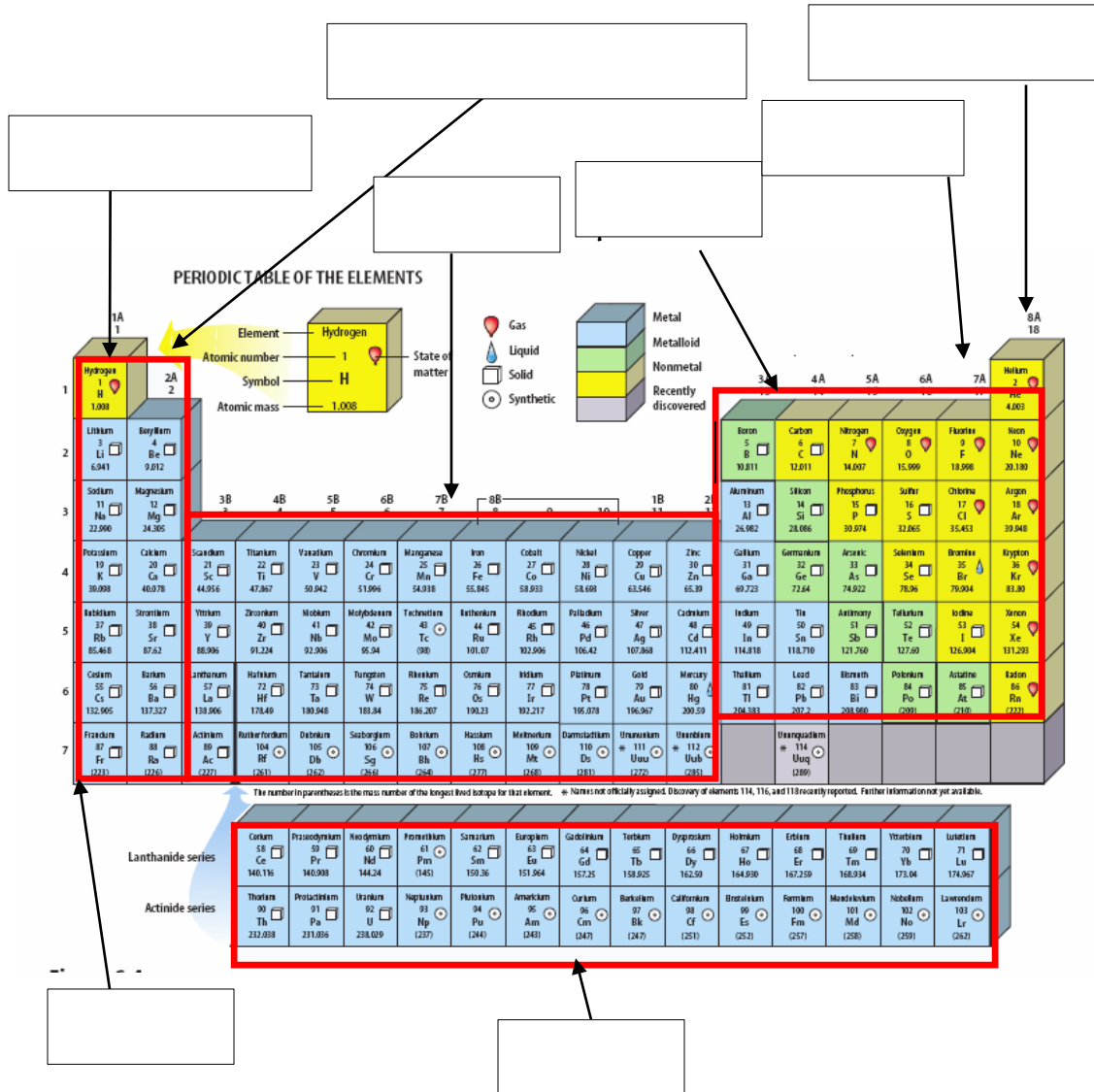
atomic mass

metal

nonmetal

metalloid

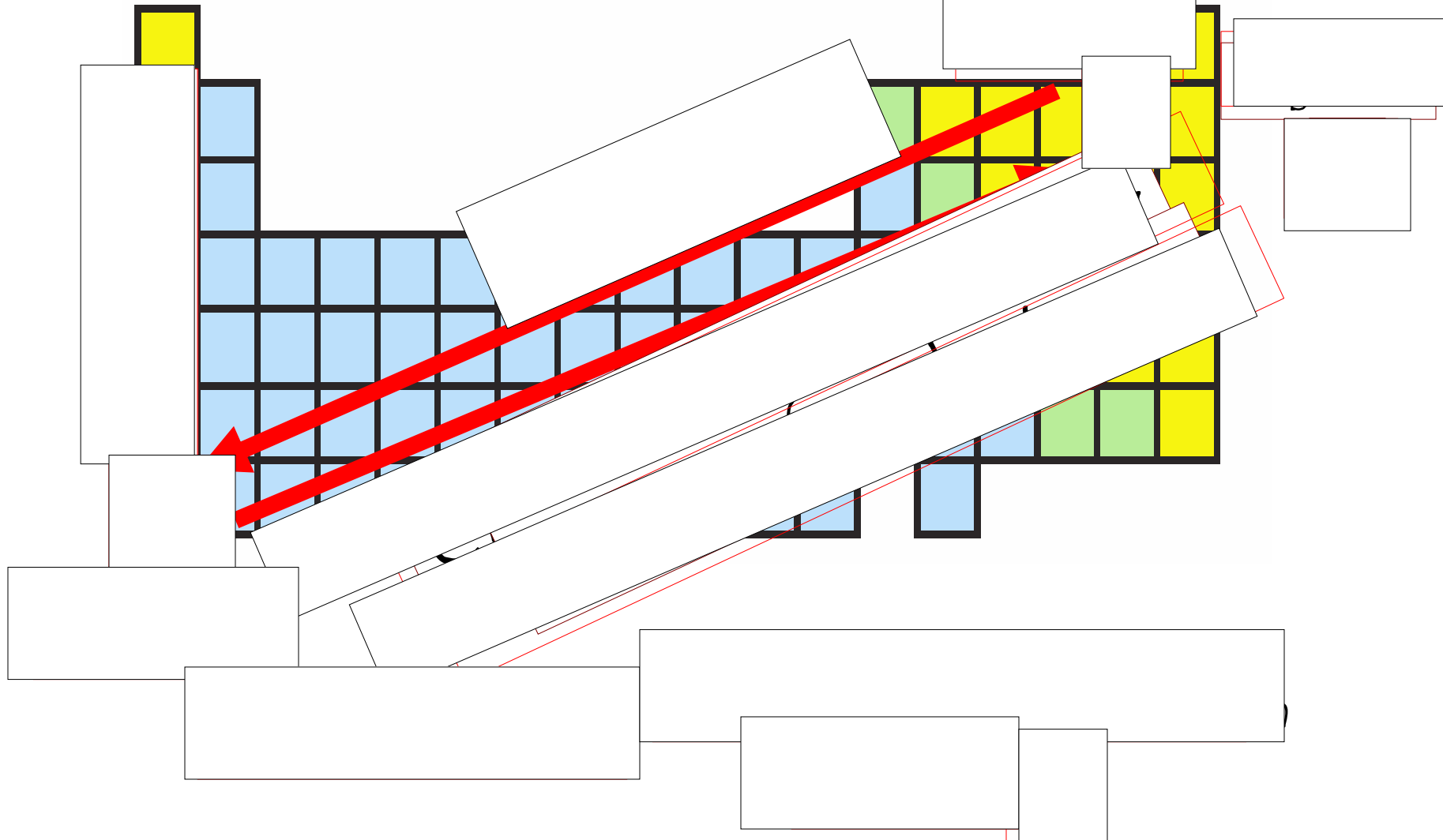
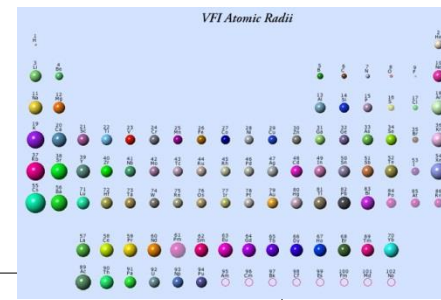
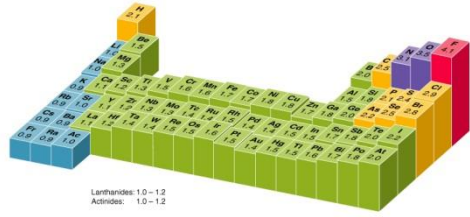
periodic table feature check



oxygen
tungsten
silicon

metal?			
block			
valence electrons			
charge			
period			
largest			
most electro-negative			
most massive			

periodic trends



atomic radius (nm)

the size of an atom increases as with each shell, but decreases in a shell with charge.

177 Atomic Radii

Periodic Table of the Elements
College of Saint Benedict / Saint John's University

periodic trends

similar chemical properties

melting point group 1

atomic/cationic size

mass, anionic size

melting point group 17

electronegativity, electron affinity, ionization energy

electronegativity (paulings)

increases as valence shell becomes closer to full, decreases with shielding

Lanthanides: 1.0 - 1.2
Actinides: 1.0 - 1.2

ionic radius (nm)

Relative Ionic Radii
College of Saint Benedict / Saint John's University

scale: 1 Å radius

some neutral atoms for reference

Size of Atoms and Their Ions in PM

Group 1	Group 2	Group 13	Group 16	Group 17
Li ⁺ 90	Be ²⁺ 134	B ³⁺ 59	O ²⁻ 126	F ⁻ 119
Na ⁺ 116	Mg ²⁺ 154	Al ³⁺ 82	S ²⁻ 170	Cl ⁻ 167
K ⁺ 138	Ca ²⁺ 196	Ga ³⁺ 114	Se ²⁻ 199	Br ⁻ 182
Rb ⁺ 152	Sr ²⁺ 211	In ³⁺ 144	Te ²⁻ 207	I ⁻ 206

electron affinity (kJ/mol)

Magnitude of electron affinity (kJ/mol), s-, p-, and d-block elements

Increasing

Increasing

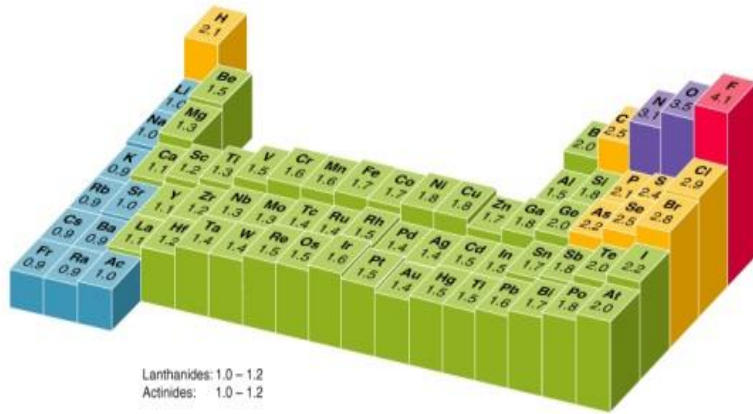
■ s block ■ p block ■ d block ■ f block

the energy released when an atom gains an electron increases toward fluorine but is very group-specific

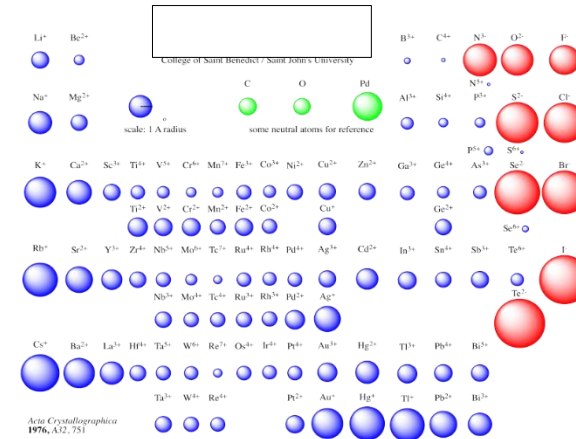
Trends for Ionic Charge

+1	+2	+3	-3	-2	-1	0
1 H Hydrogen	4 Be Beryllium		7 N Nitrogen	8 O Oxygen	9 F Fluorine	2 He Helium
3 Li Lithium	12 Mg Magnesium		15 P Phosphorus	16 S Sulfur	17 Cl Chlorine	10 Ne Neon
11 Na Sodium	20 Ca Calcium	13 Al Aluminum	34 Se Selenium	35 Br Bromine	36 Kr Krypton	18 Ar Argon
19 K Potassium	38 Sr Strontium	30 Zn Zinc	47 Ag Silver	48 Cd Cadmium	53 I Iodine	36 Kr Krypton
37 Rb Rubidium	56 Ba Barium				54 Xe Xenon	10 Ne Neon
55 Cs Cesium	88 Ra Radium				86 Rn Radon	18 Ar Argon
87 Fr Francium						36 Kr Krypton

name that trend



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introduction to chemical bonds



what is a chemical bond?

which elements do not form chemical bonds?

why do elements form bonds?

if the bond is between _____

it is a _____ bond

example



or

some added detail: polarity of covalent bonds

bond	type
H ₃ C-CH ₃ (same nonmetals)	<div style="border: 1px solid black; height: 40px;"></div>
H ₃ C-OH (different nonmetals)	<div style="border: 1px solid black; height: 40px;"></div>
H ₃ C-H (an exception)	<div style="border: 1px solid black; height: 40px;"></div>

type of bond?

Na-Cl

F-F

P-O

Cl-Mg-Cl

O=C=O

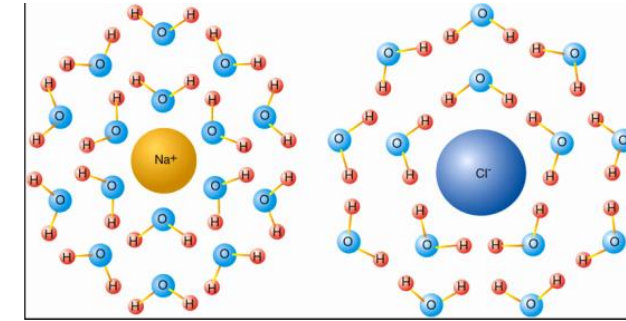
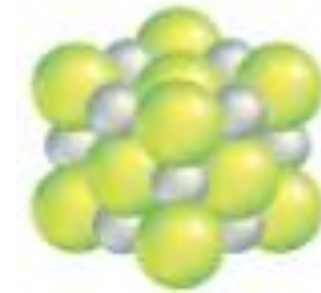
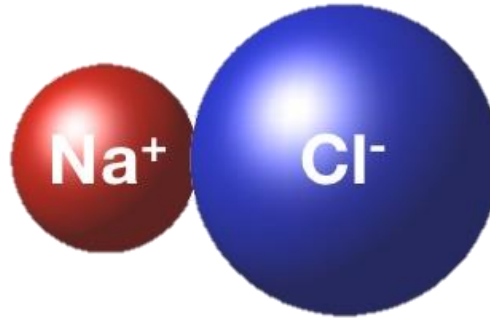
Na-OH

Fe-Fe

C-C (graphite)

properties of ionic bonds (salts)

Periodic table highlighting the groups of elements that form ionic bonds: Group 1 (IA) and Group 17 (VIIA).



melting point $801\text{ }^\circ\text{C}$

~~bond~~ lattice energy 787 kJ/mol

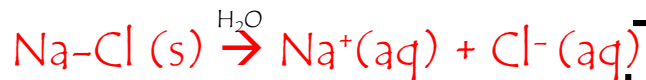
metal⁺-nonmetal⁻

oppositely charged ions

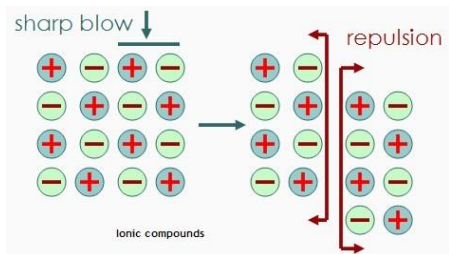
not individual molecules

dissolve in water

chemical equation for table salt dissolving in water:



(aq)? **aqueous**



ionic compounds are brittle

names and formulas

cation	anion	name	charges	formula: switch the charge numbers
Na	Cl	sodium chloride	$\text{Na}^{+1} \text{Cl}^{-1}$	NaCl
Mg	F	magnesium fluoride	$\text{Mg}^{+2} \text{F}^{-1}$	MgF_2

a couple of things about ions

ions are not always from single atoms:

many ions have multiple charges

Ex: ${}_{22}\text{Ti}^{4+}$ titanium

ions can be

ions can be



TABLE OF POLYATOMIC IONS															
acetate	CH_3COO^-	dihydrogen phosphate	H_2PO_4^-	perchlorate	ClO_4^-										
arsenate	AsO_4^{3-}	hydrogen carbonate	HCO_3^-	periodate	IO_4^-										
arsenite	AsO_3^{3-}	hydrogen oxalate	HC_2O_4^-	permanganate	MnO_4^-										
benzoate	$\text{C}_6\text{H}_5\text{COO}^-$	hydrogen sulfate	HSO_4^-	peroxide	O_2^{2-}										
borate	BO_3^{3-}	hydrogen sulfide	HS^-	phosphate	PO_4^{3-}										
bromate	BrO_3^-	hydrogen sulfite	HSO_3^-	pyrophosphate	$\text{P}_2\text{O}_7^{4-}$										
carbonate	CO_3^{2-}	hydroxide	OH^-	sulfate	SO_4^{2-}										
chlorate	ClO_3^-	hypochlorite	ClO^-	sulfite	SO_3^{2-}										
chloride	Cl^-	iodate	IO_3^-	thiocyanate	SCN^-										
chlorite	ClO_2^-	monohydrogen phosphate	HPO_4^{2-}	thiosulfate	$\text{S}_2\text{O}_3^{2-}$										
chromate	CrO_4^{2-}	nitrate	NO_3^-	POSITIVE POLYATOMIC IONS											
cyanate	CNO^-	nitrite	NO_2^-	ammonium	NH_4^+										
cyanide	CN^-	orthosilicate	SiO_4^{4-}	hydronium	H_3O^+										
dichromate	$\text{Cr}_2\text{O}_7^{2-}$														

PERIODIC TABLE OF IONS																	
KEY																	
atomic number	ion charge		ion name (IUPAC)														
	26	Fe^{3+}	iron (III)	iron (III)	17	H^-	hydride	2	He	helium							
		27	Fe^{2+}	iron (II)													
				iron (II)													
1	H^+	hydrogen	2														
3	Li^+	lithium	4	Be^{2+}	beryllium												
11	Na^+	sodium	12	Mg^{2+}	magnesium												
19	K^+	potassium	20	Ca^{2+}	calcium	21	Sc^{3+}	scandium	22	Ti^{4+}	titanium (IV)	23	V^{3+}	vanadium (III)	24	Cr^{3+}	chromium (III)
27	Rb^+	rubidium	38	Sr^{2+}	strontium	39	Y^{3+}	yttrium	40	Zr^{4+}	zirconium (IV)	41	Nb^{5+}	niobium (V)	42	Mo^{6+}	molybdenum (VI)
55	Cs^+	cesium	56	Ba^{2+}	barium	57	La^{3+}	lanthanum	72	Hf^{4+}	hafnium	73	Ta^{5+}	tantalum	74	W^{6+}	tungsten (VI)
87	Fr^+	francium	88	Ra^{2+}	radium	89	Ac^{3+}	actinium									

configuration?

why are these elements polyvalent?

how to name them?

formula

name

titanium (IV) chloride

TiCl_2

iron (II) cyanide

Formula: NaCl . Name?

rock =

chemical name

charges

formula

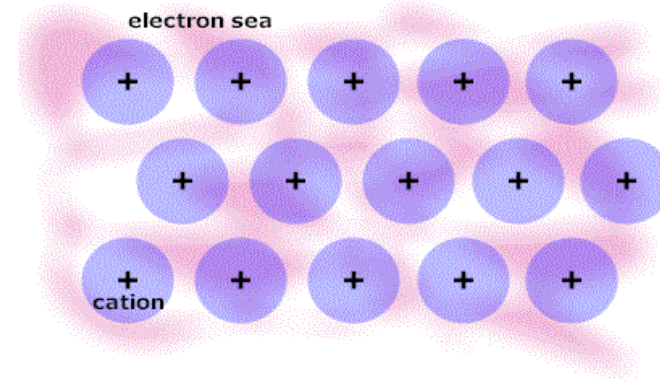
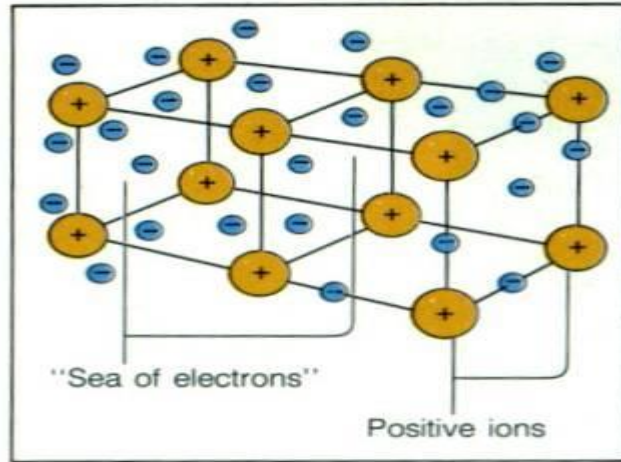
polyatomic ion =

sodium cyanide

calcium hydroxide

Other examples:

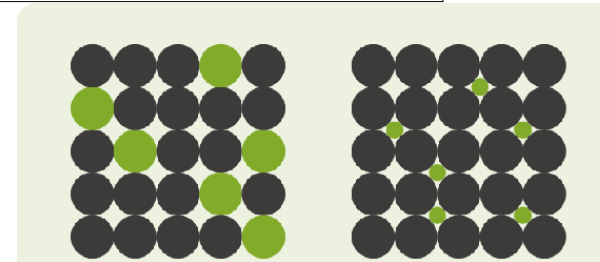
metallic bonds



metallic bonds are in general

examples:

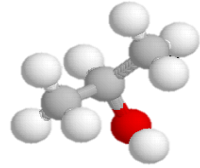
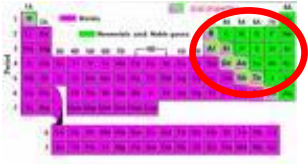
alloys



two types of alloys:

covalent bonding:

a bond based on electrons



how does electron sharing work?

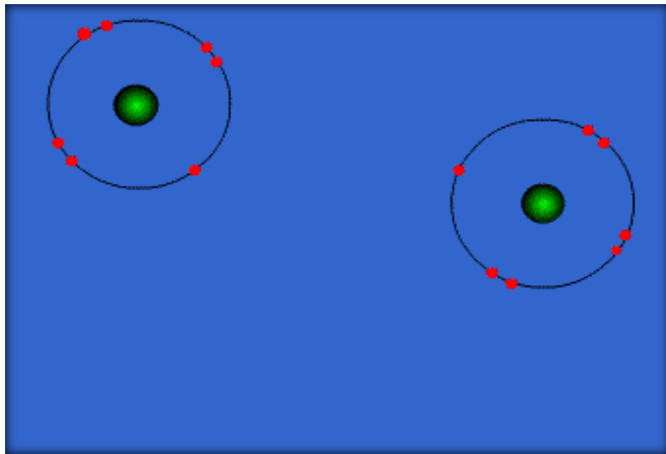
atoms share electrons to:

electron dot structures: the outer shell

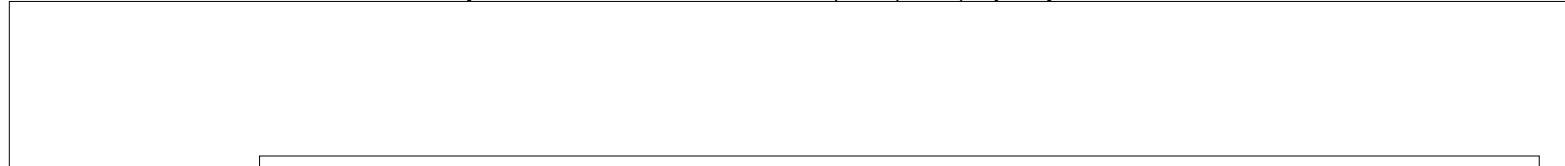
8 electrons (except H, He)
Paired (Pauli), spread out (Hunds).

neon:

8 valence electrons



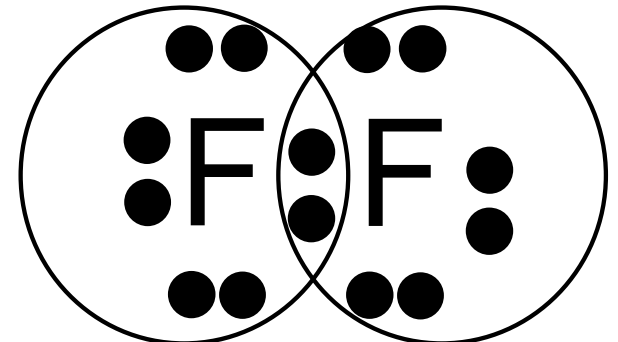
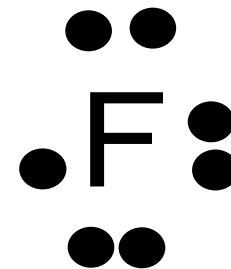
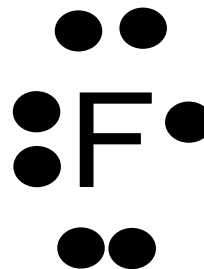
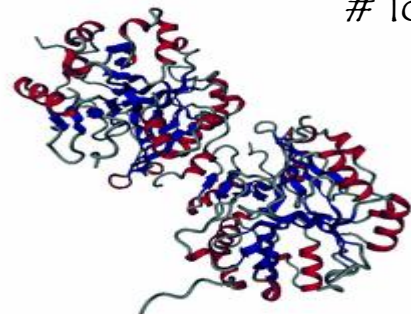
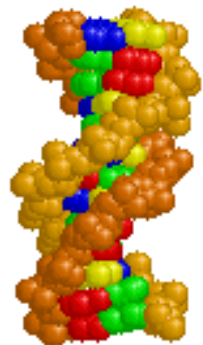
write the electron dot structures of H, O, N, and C:



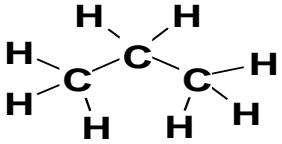
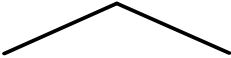
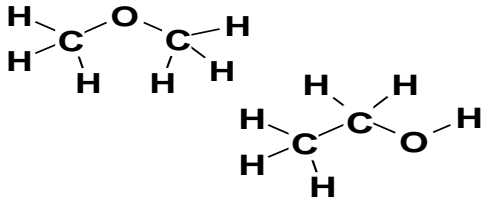
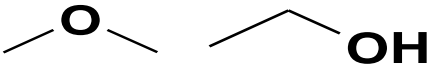
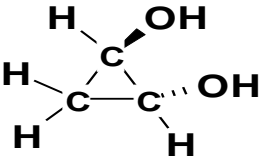
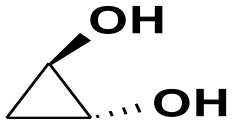
bonds:



lone pairs:



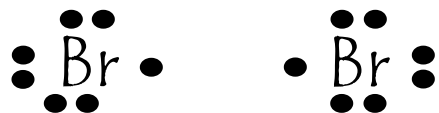
common chemical formula types

molecular formula	structural formula	skeletal formula	condensed formula
C_3H_8			$CH_3CH_2CH_3$
C_2H_6O (2 isomers)			CH_3OCH_3 CH_3CH_2OH
$C_3H_6O_2$ (1 isomer)			-----

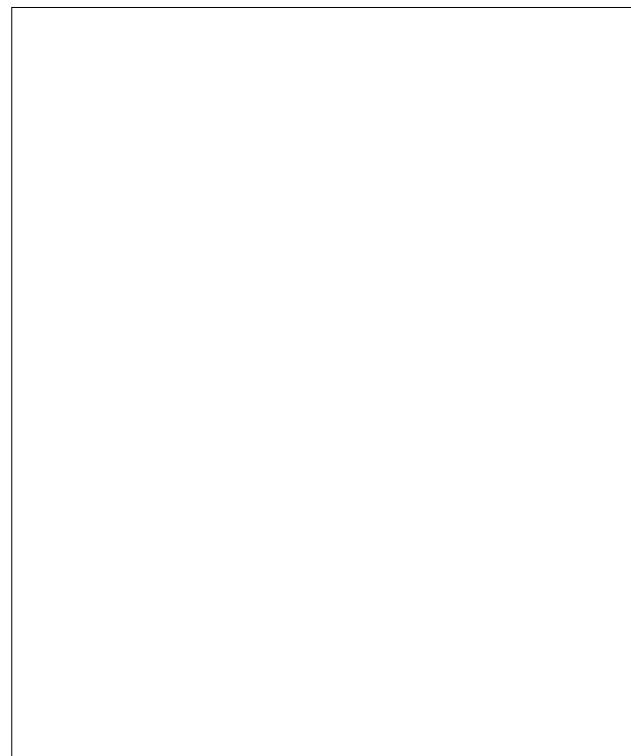
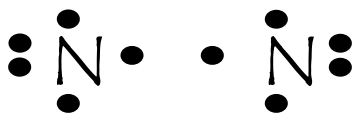
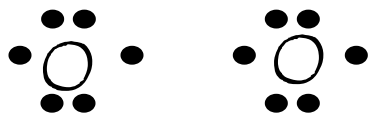
the diatomic elements

H. BrONClIF

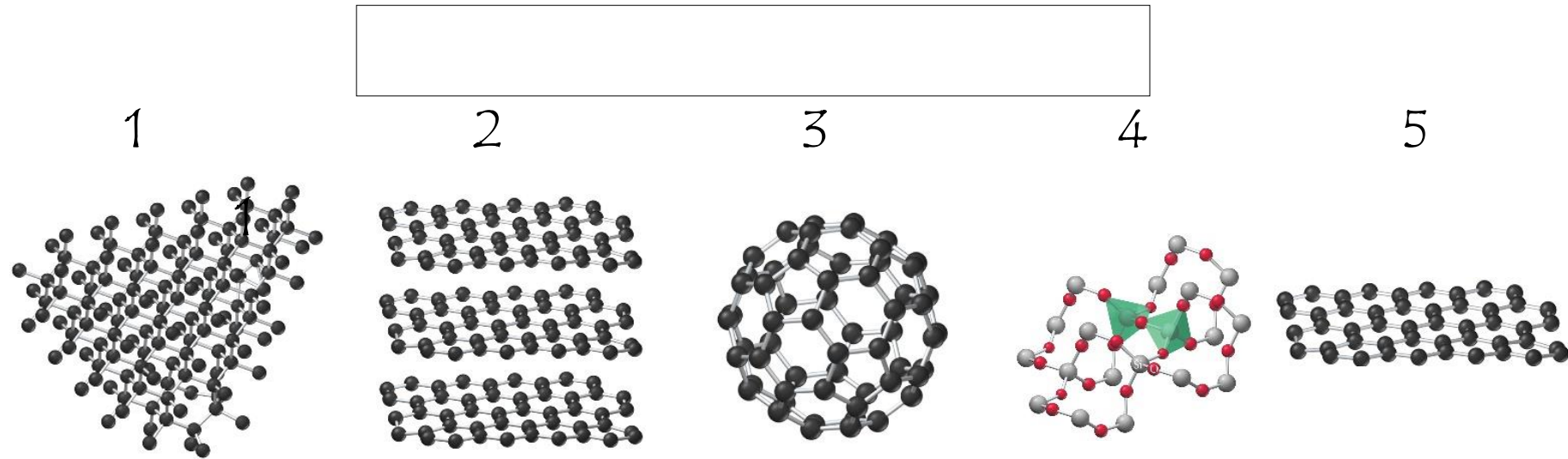
combine them to form octets (except H, which only needs 2);
multiple bonds are possible.



(Same for Cl, I, F)



covalent network solids



Similar to metals but with nonmetallic elements.

graphite quartz buckminsterfullerene graphene diamond

name some
others:

B

BN

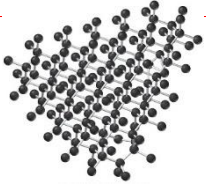
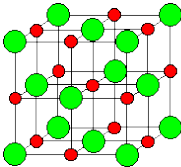
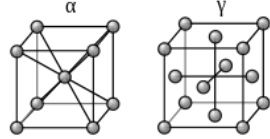
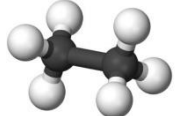
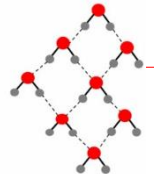
ReB₂

SiC

Si

Ge

chemical bonds and intermolecular forces

	bond or force	strength (kJ/mol)	example	substance	bonds/forces present	
networked substances (no individual molecules)	network covalent bond	300 – 5000	C-C (diamond)			
	ionic bond	400-4000	Na ⁺ -Cl ⁻			
	metallic bond	100-500	Fe-Fe			
intramolecular	covalent bond	150-1100	C-C (molecules)			
intermolecular	ion-dipole force	40-600	Na ⁺ --OH ₂			
	hydrogen bond force F, O, N-H--:F, O, N	10-200	HO-H--OH ₂			
	dipole-dipole force	5-25	CO ₂ --CO ₂			
	London dispersion force (induced dipole)	0.05-40	N ₂ --N ₂			

If the ionic bonds break but do not form new bonds the substance is

If the ions are in solution and the ionic bond forms the substance has

If the substance has no intermolecular forces it must be a

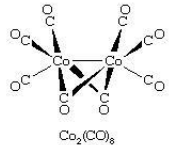
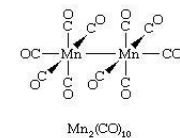
If the substance has intermolecular forces that are fixed it must be a

If the substance has fluid intermolecular forces it is a

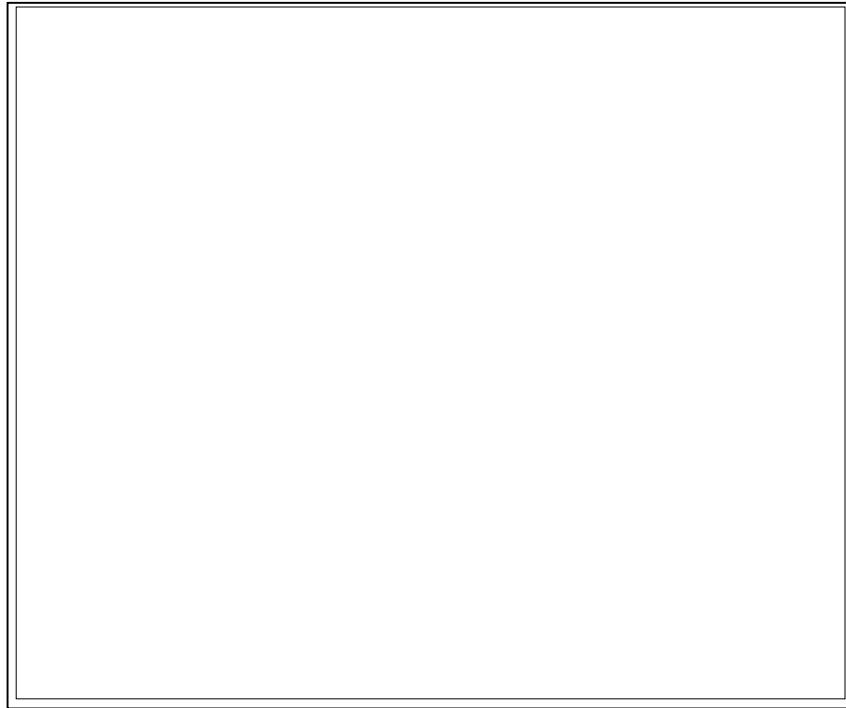
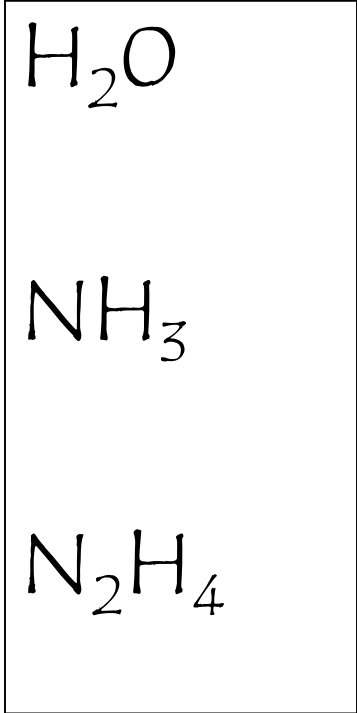
Why is HF nearly a liquid at room temperature but HCl is a gas at room temp?

What is the strongest intermolecular force in N₂ CO₂ H₂O HF

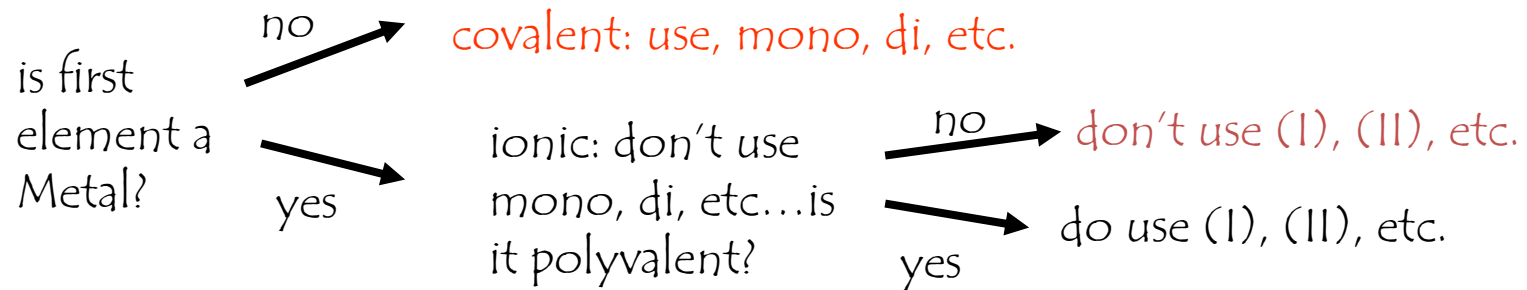
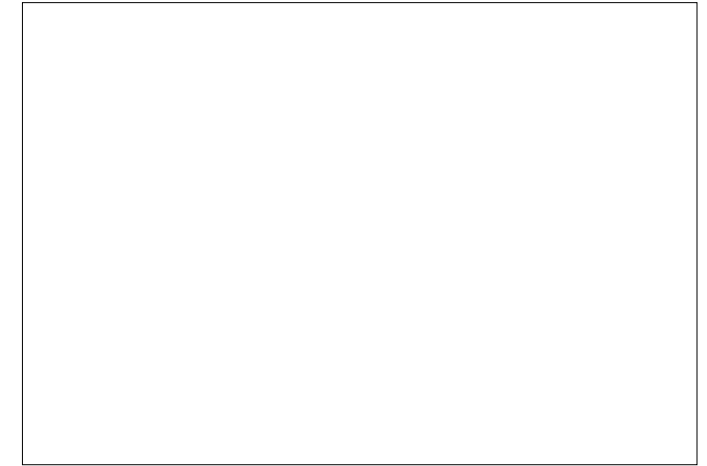
CH₃OH CCl₄



naming binary molecules

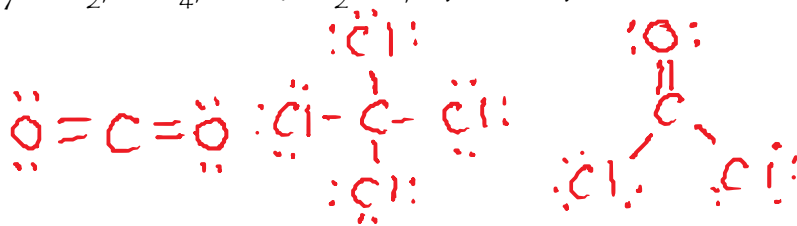
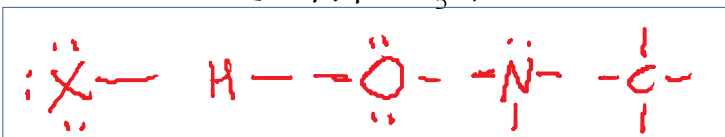


naming: covalent vs. ionic



how to determine the shapes of lots of molecules

1. If only X,H,O,N,C apply rules, done. (try CO_2 , CCl_4 , even Cl_2CO ; fails for a few like CO and NO_3^-)



Otherwise:

1. Add up valence electrons
2. Create framework around a central atom; which can have up to 2-6 bonds (incomplete or expanded octet); add electrons to center or create double bonds until valence electrons match
3. Minimize formal charges by forming double bonds; note that only Al and higher can form expanded octets

Group 4A Group 5A Group 6A Group 7A Group 8

SiF_5^- PF_5 SF_4 ClF_3 XeF_2

SiF_6^{2-} PF_6^- SF_6 BrF_5 XeF_4

VSEPR

valence shell electron pair repulsion theory

Number of Electron Dense Areas	Electron-Pair Geometry	Molecular Geometry				
		No Lone Pairs	1 lone Pair	2 lone Pairs	3 lone Pairs	4 lone Pairs
2 	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
3 	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
4 	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
5 	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
6 	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>