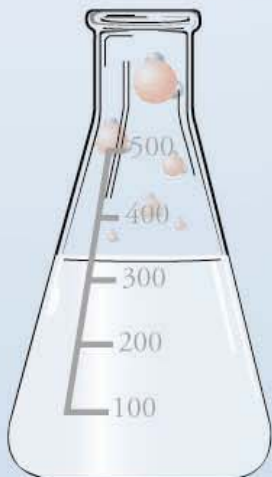
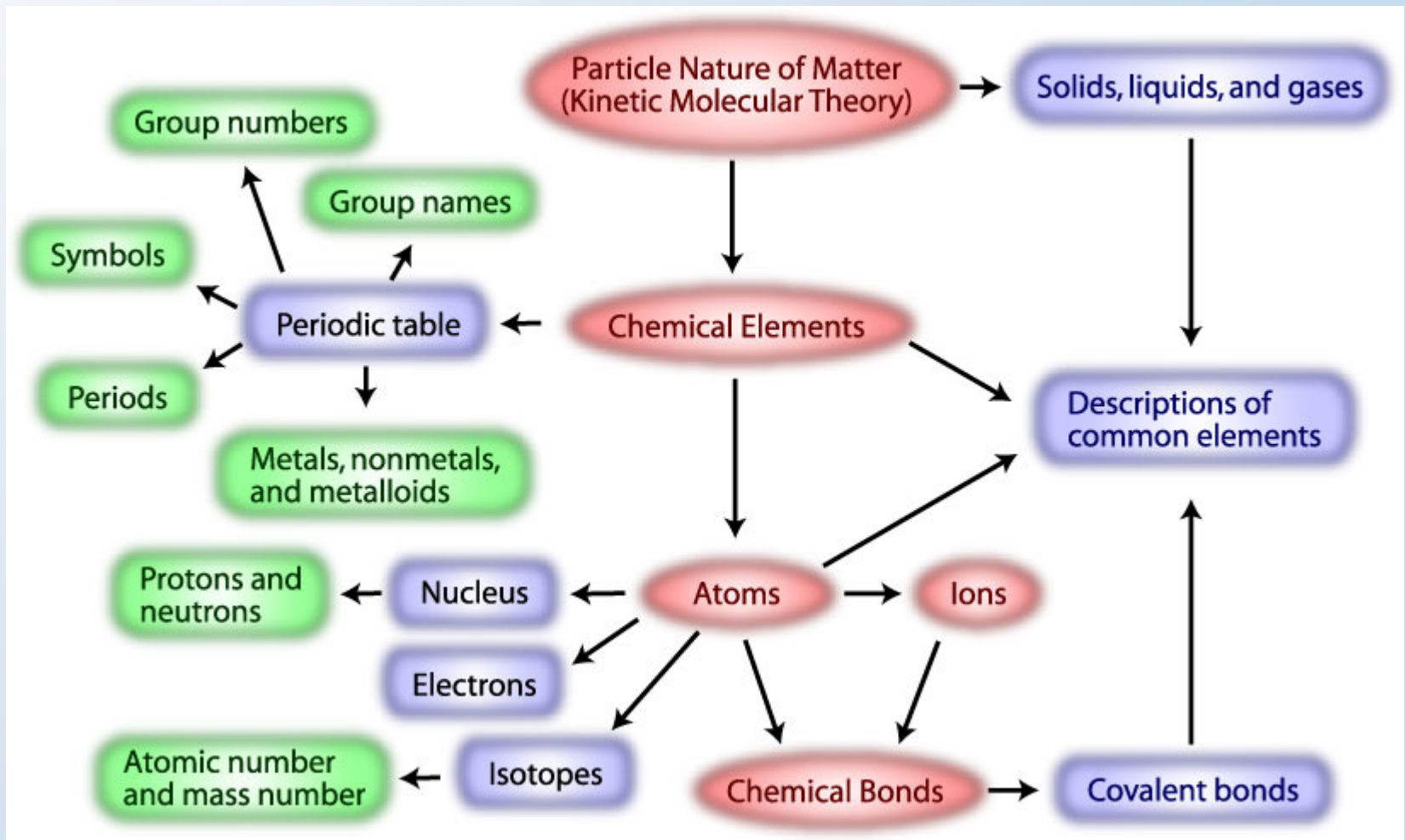


# Chapter 3

## The Structure of Matter and the Chemical Elements



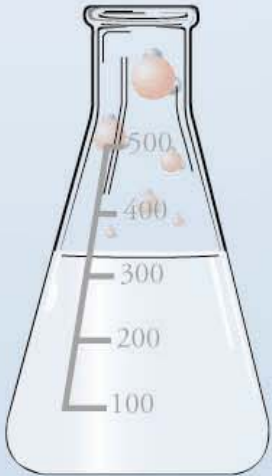
# Chapter Map



A vertical column of water molecules (H<sub>2</sub>O) is positioned on the left side of the slide. Each molecule consists of one red oxygen atom and two black hydrogen atoms. The molecules are arranged in a descending sequence from top to bottom, with some appearing to be inside the flask.

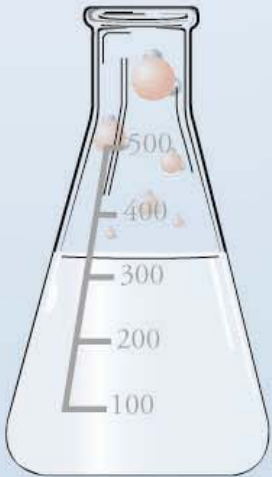
# Chemistry

The science that deals with the structure and behavior of matter



# Scientific Models

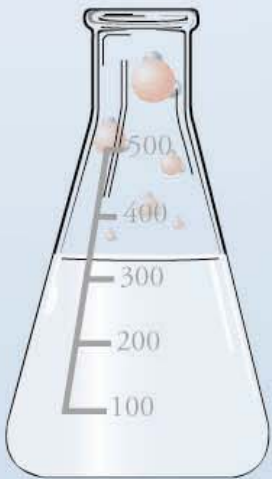
- A ***model*** is a simplified approximation of reality.
- Scientific models are simplified but *useful* representations of something real.



A series of water molecules, each consisting of one large red sphere (oxygen) and two smaller black spheres (hydrogen), arranged in a descending arc from the top left towards the center of the slide.

# Kinetic Molecular Theory

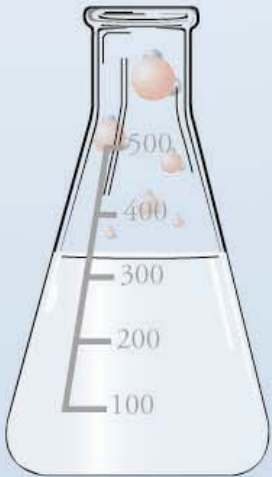
- All matter is composed of tiny particles.
- The particles are in constant motion.
- Increased temperature indicates increased motion of the particles.
- Solids, liquids and gases differ in the freedom of motion of their particles and in how strongly the particles attract each other.



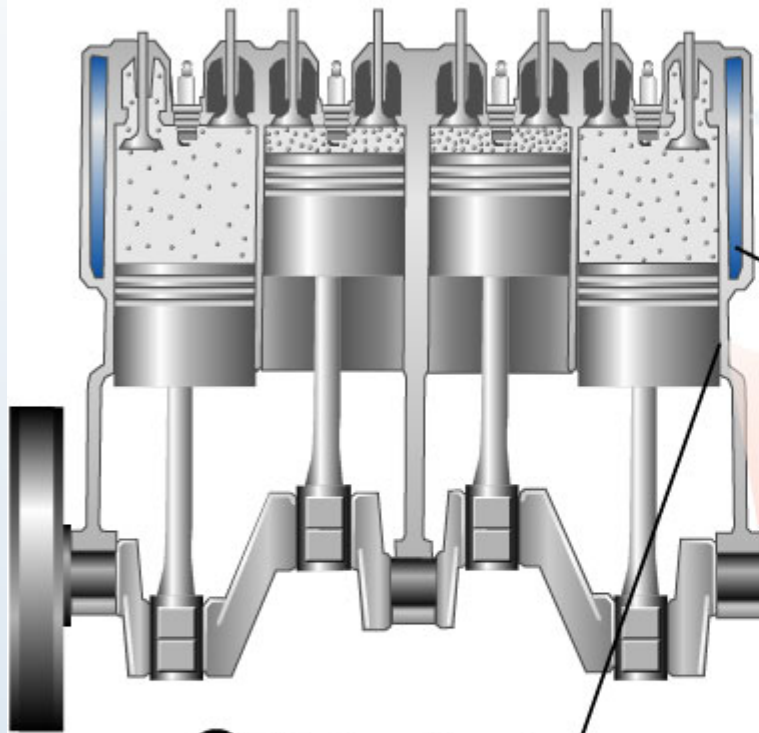
A vertical column of water molecules (H<sub>2</sub>O) is shown on the left side of the slide. Each molecule consists of one large red sphere (oxygen) and two smaller black spheres (hydrogen) bonded to it. The molecules are arranged in a somewhat regular, repeating pattern, representing the solid state of water (ice).

# Solid

- Constant shape and volume
- The particles are constantly moving, colliding with other particles, and changing their direction and velocity.
- Each particle is trapped in a small cage whose walls are formed by other particles that are strongly attracted to each other.

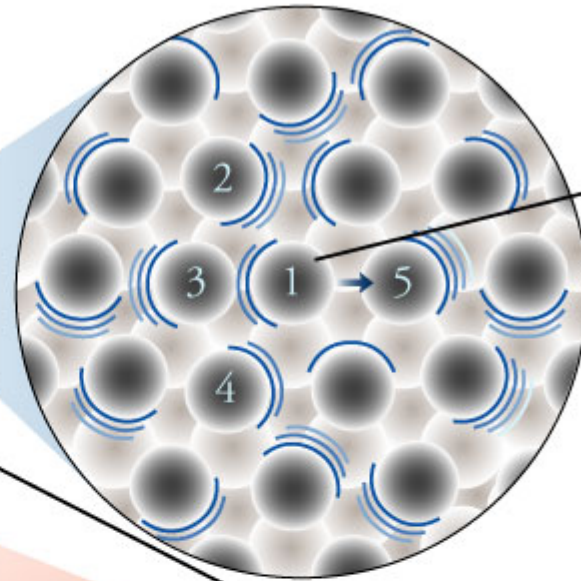


# The Nature of Solids

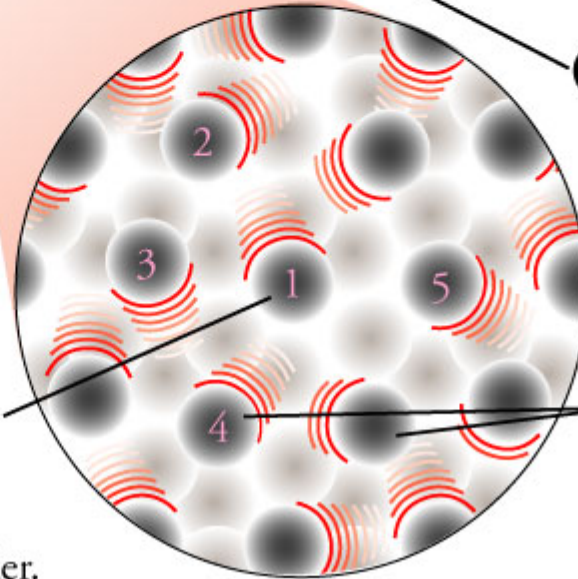


**1** Friction of moving parts causes temperature to rise.

**2** As temperature rises, particles move faster and bump harder.



Moving particles bump and tug one another but stay in the same small space.

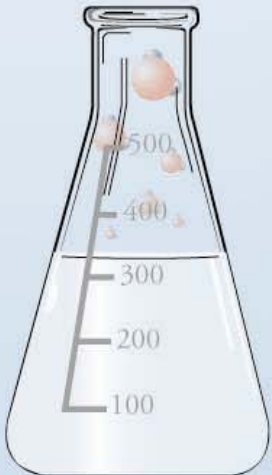


**4** If the lubricating or cooling system fails, engine expansion may cause a piston to jam in the cylinder.

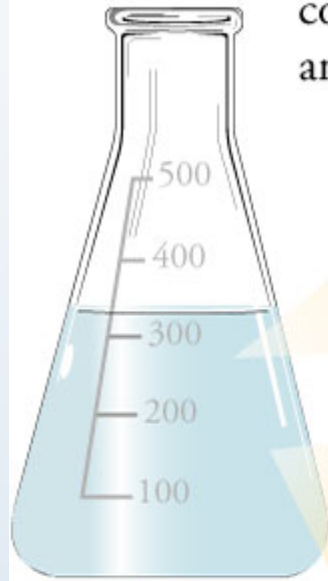
**3** Neighboring particles are pushed farther apart, and the solid expands.

# Liquid

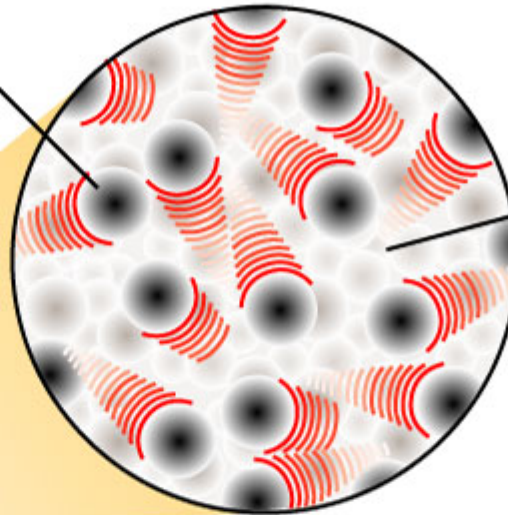
- Constant volume but variable shape
- The particles are moving fast enough to break the attractions between particles that form the walls of the cage that surround particles in the solid form.
- Thus each particle in a liquid is constantly moving from one part of the liquid to another.



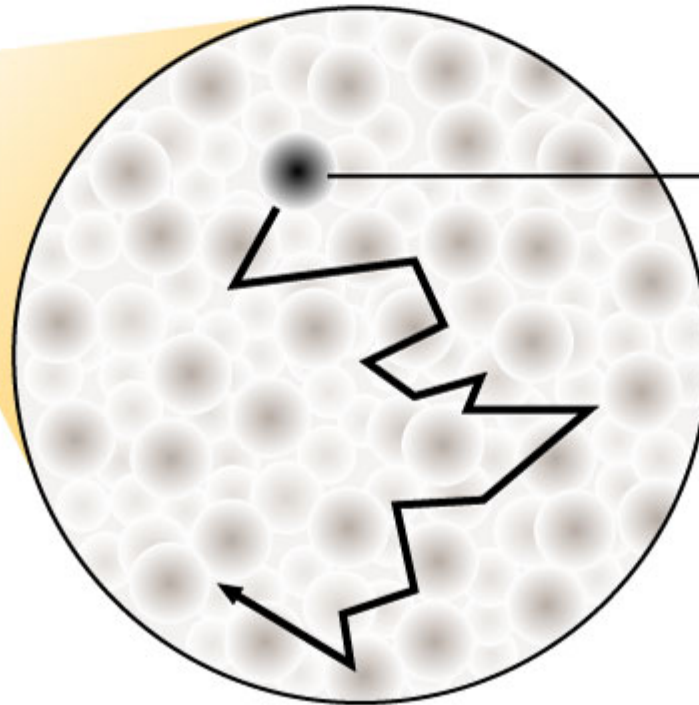




Particles move fast enough for attractions to be constantly broken and reformed.



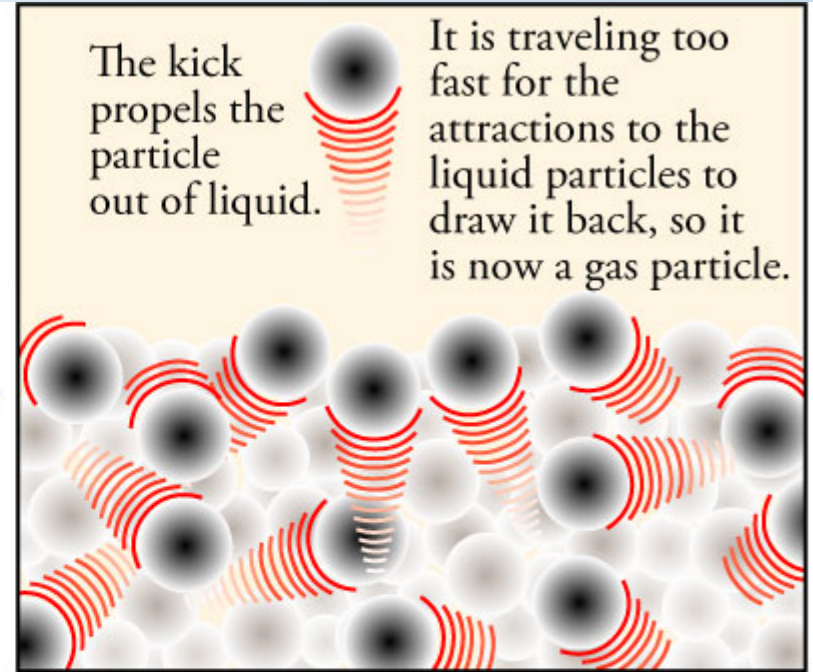
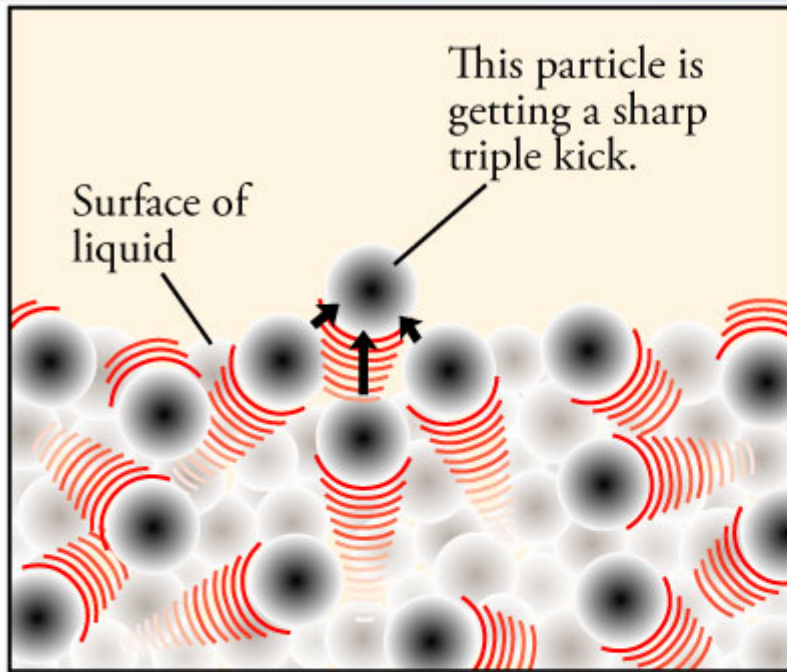
Particles are less organized, with slightly more space between them than in the solid.



Particles move throughout the container.

# Liquids

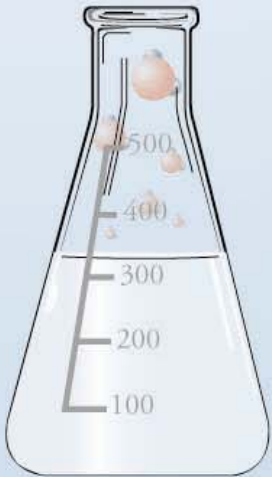
# Evaporation



A vertical column of water molecules (H<sub>2</sub>O) is shown on the left side of the slide. Each molecule consists of one large red sphere (oxygen) and two smaller black spheres (hydrogen) bonded to it. The molecules are arranged in a descending staircase pattern from top to bottom.

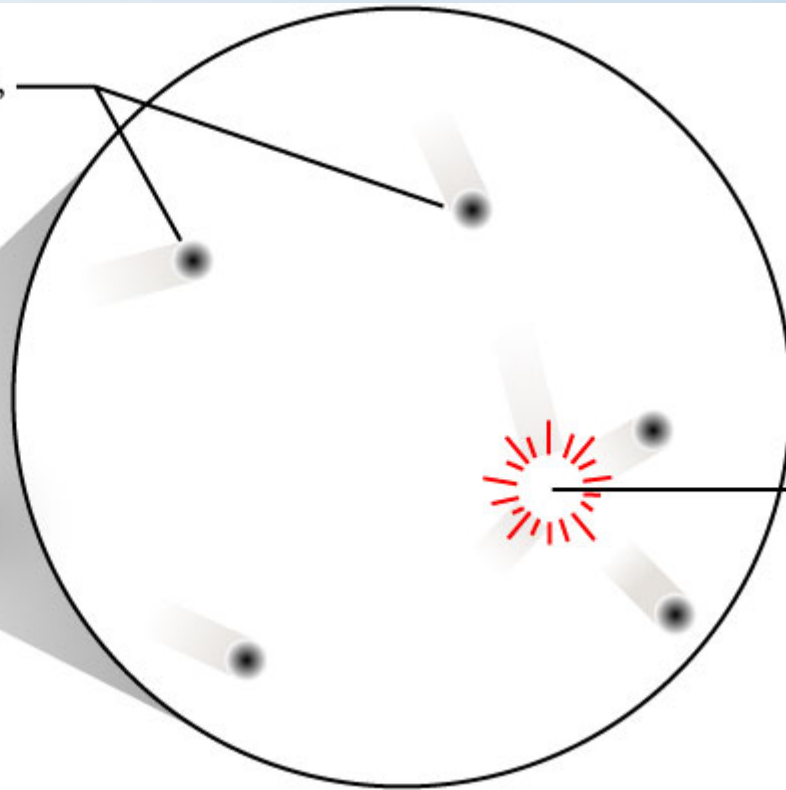
# Gas

- Variable shape and volume
- Large average distances between particles
- Little attraction between particles
- Constant collisions between particles, leading to constant changes in direction and velocity



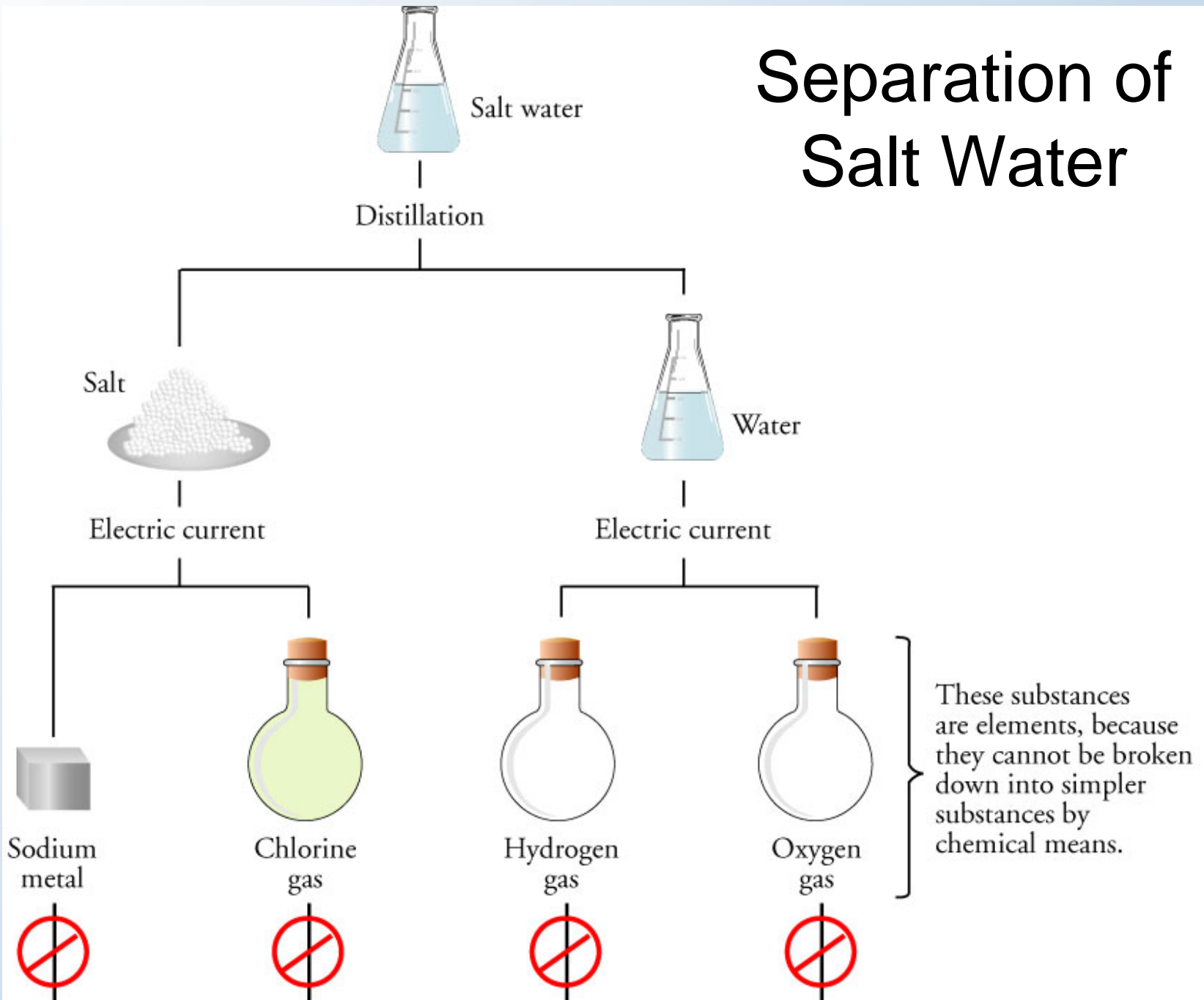
# The Nature of Gases

Because particles are so far apart, there is usually no significant attraction between them.

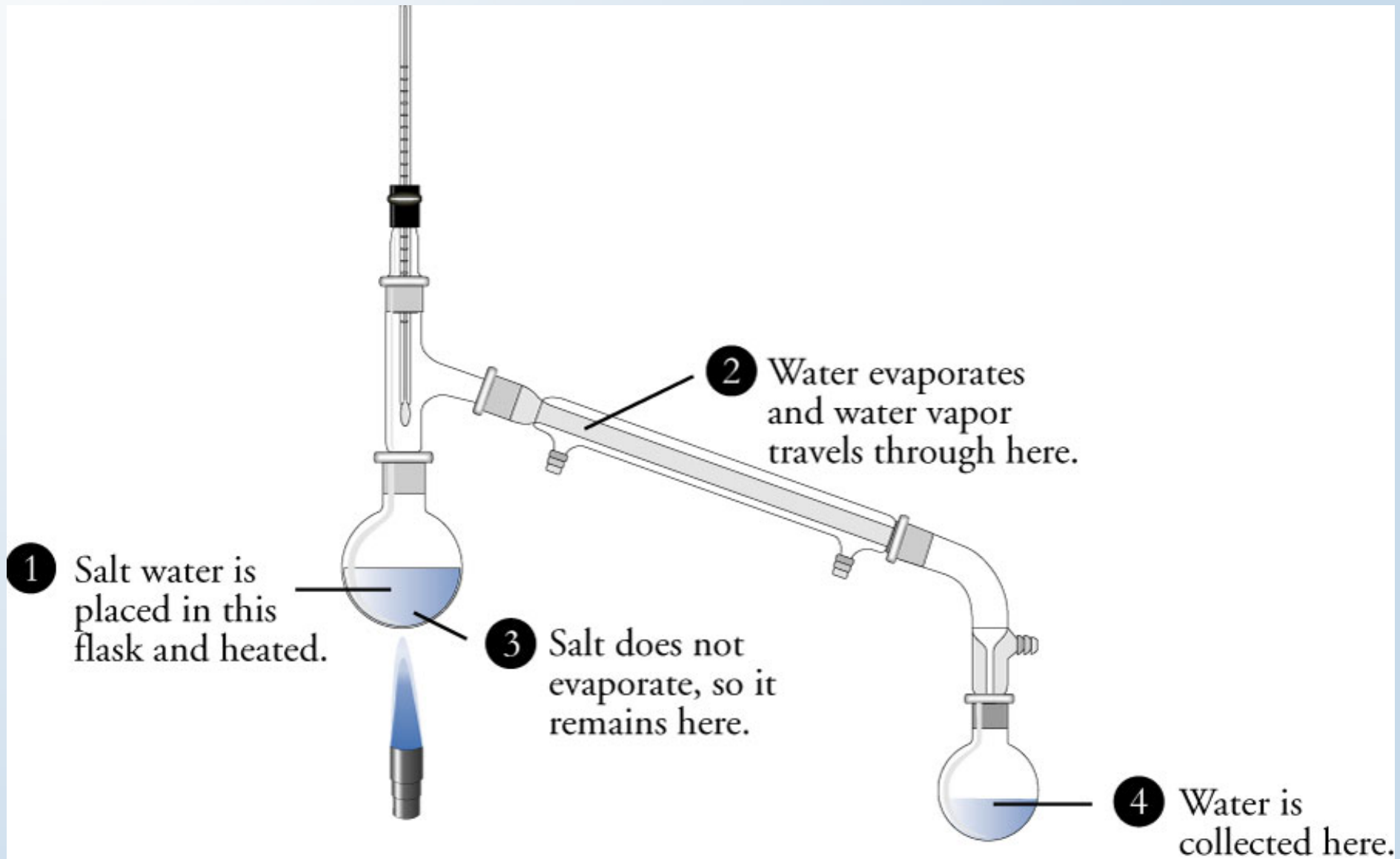


Particles move in straight paths, changing direction and speed when they collide.

# Separation of Salt Water



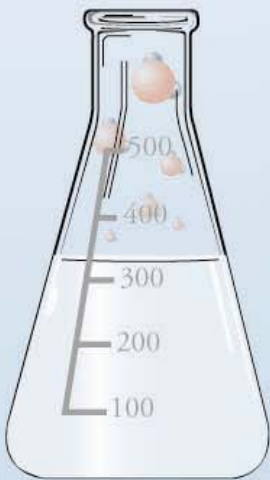
# Distillation





# 114+ Known Elements

- 83 are stable and found in nature.
  - Many of these are very rare.
- 7 are found in nature but are radioactive.
- 24+ are not natural on the earth.
  - 2 or 3 of these might be found in stars.



# Group Numbers on the Periodic Table

	1	2											13	14	15	16	17	18		
	1A	2A											3A	4A	5A	6A	7A	8A		
1														1						2
2	3	4											5	6	7	8	9	10		
	Li	Be											B	C	N	O	F	Ne		
3	11	12	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18		
	Na	Mg	3B	4B	5B	6B	7B	8B	8B	8B	1B	2B	Al	Si	P	S	Cl	Ar		
4	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36		
	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr		
5	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54		
	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe		
6	55	56	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86		
	Cs	Ba	Lu	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn		
7	87	88	103	104	105	106	107	108	109	110	111	112		114		116				
	Fr	Ra	Lr	Rf	Db	Sg	Bh	Hs	Mt	Ds	Uuu	Uub		Uuq		Uuh				
6			57	58	59	60	61	62	63	64	65	66	67	68	69	70				
			La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb				
7			89	90	91	92	93	94	95	96	97	98	99	100	101	102				
			Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No				

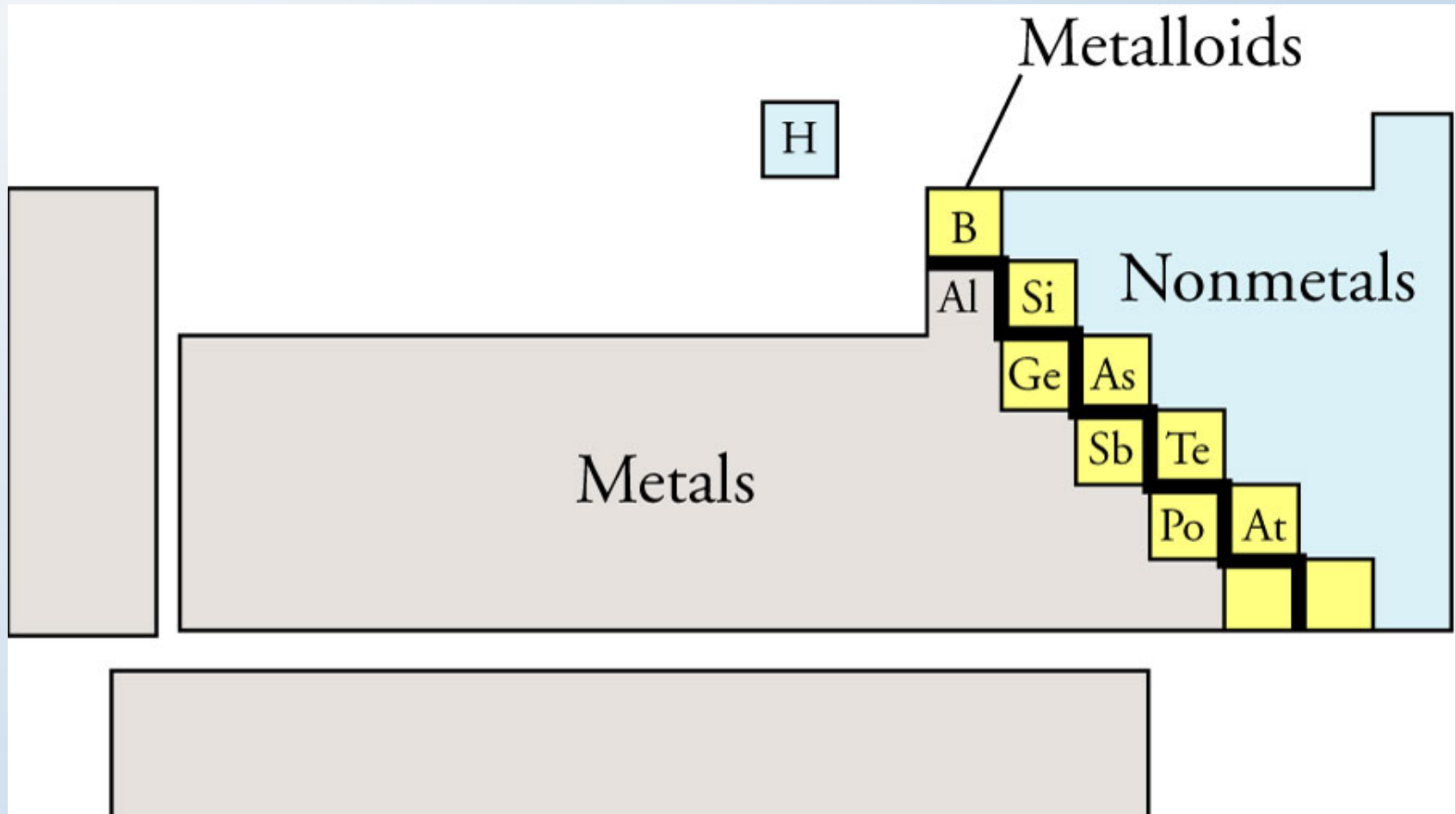


# Group Names

Alkali Metals      Alkaline Earth Metals      Halogens      Noble Gases

	1 1A	2 2A											13 3A	14 4A	15 5A	16 6A	17 7A	18 8A	
1													1 H						
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne	
3	11 Na	12 Mg	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9 8B	10 8B	11 1B	12 2B	13 Al	14 Si	15 P	16 S	17 Cl	18 Ar	
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr	
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe	
6	55 Cs	56 Ba	71 Lu	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn	
7	87 Fr	88 Ra	103 Lr	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Uuu	112 Uub		114 Uuq		116 Uuh			
			6	57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb		
			7	89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No		

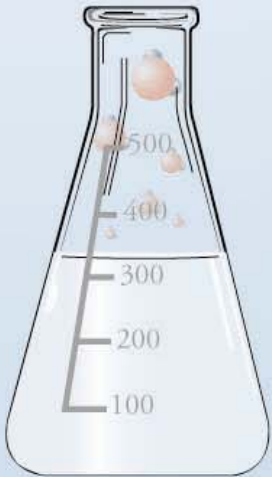
# Metals, Nonmetals, and Metalloids



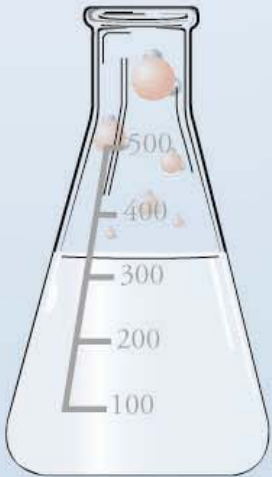
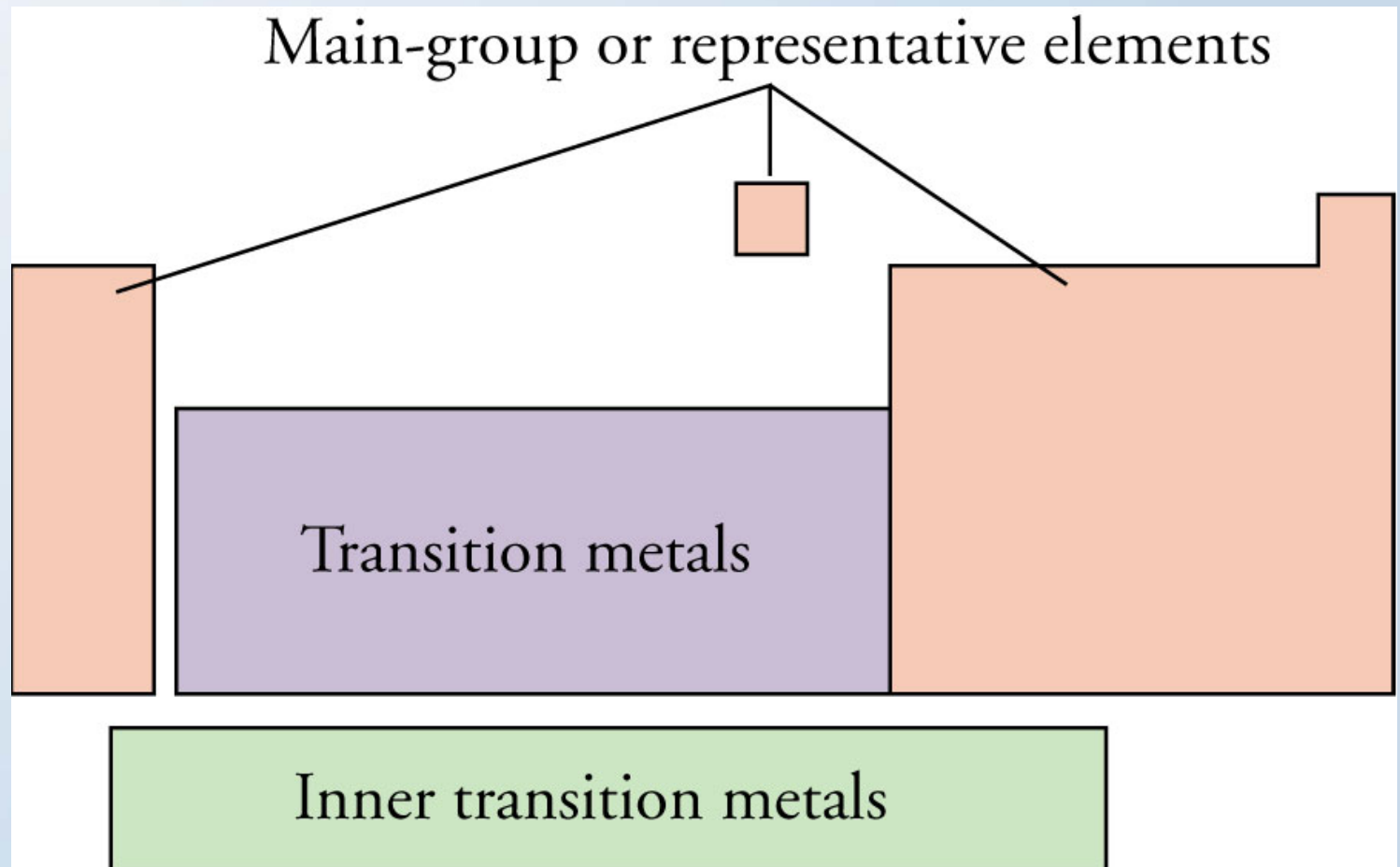


# Characteristics of Metallic Elements

- Metals have a shiny metallic luster.
- Metals conduct heat well and conduct electric currents in the solid form.
- Metals are malleable.
  - For example, gold, Au, can be hammered into very thin sheets without breaking.



# Classification of Elements







# Atoms

- **Tiny...about  $10^{-10}$  m**
  - If the atoms in your body were 1 in. in diameter, you'd bump your head on the moon.
- **Huge number of atoms in even a small sample of an element**
  - 1/2 carat diamond has  $5 \times 10^{21}$  atoms...if lined up, would stretch to the sun.

A decorative vertical column of water molecules (H<sub>2</sub>O) on the left side of the slide. Each molecule consists of one large red sphere (oxygen) and two smaller black spheres (hydrogen) bonded to it. The molecules are arranged in a slightly curved, descending line from top to bottom.

# Particles in the Atom

- **Neutron (n)**

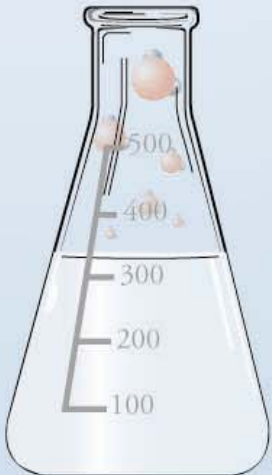
0 charge      1.00867 u      in nucleus

- **Proton (p)**

+1 charge      1.00728 u      in nucleus

- **Electron (e<sup>-</sup>)**

-1 charge      0.000549 u      outside  
nucleus



# The Electron

*“If I seem unusually clear to you, you must have misunderstood what I said.”*

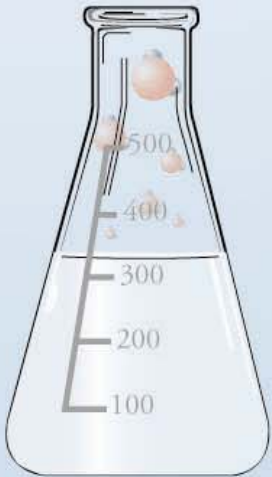
Alan Greenspan,

Head of the Federal Reserve Board

*“It is probably as meaningless to discuss how much room an electron takes up as to discuss how much room a fear, an anxiety, or an uncertainty takes up.”*

Sir James Hopwood Jeans,

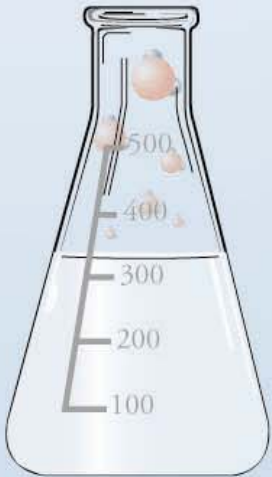
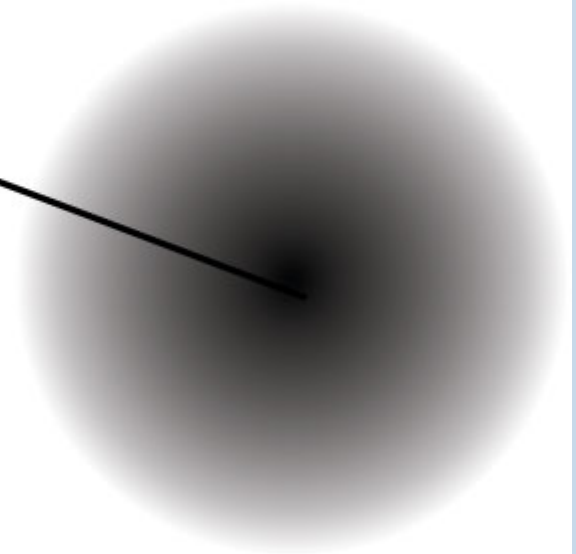
English mathematician, physicist and astronomer (1877-1946)





# Electron Cloud for Hydrogen Atom

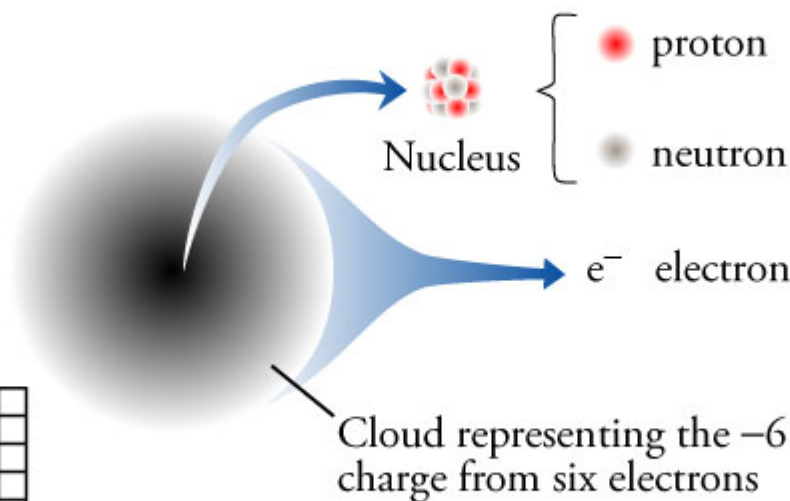
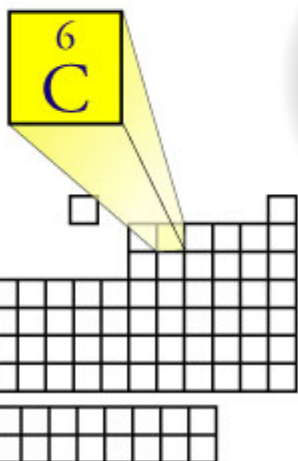
The negative charge is most intense at the nucleus and diminishes in intensity with increased distance from the nucleus.





# Carbon Atom

## Carbon atom

6 protons  
6 neutrons  
(in most carbon atoms)  
6 electrons  
(in uncharged atom)

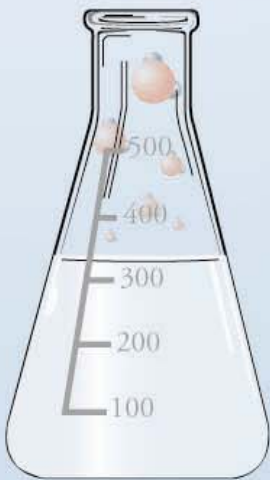


Particle	Charge	Mass
 proton	+1	1.00728 u ( $1.6726 \times 10^{-24}$ g)
 neutron	0	1.00867 u ( $1.6750 \times 10^{-24}$ g)
e <sup>-</sup> electron	-1	0.000549 u ( $9.1096 \times 10^{-28}$ g)

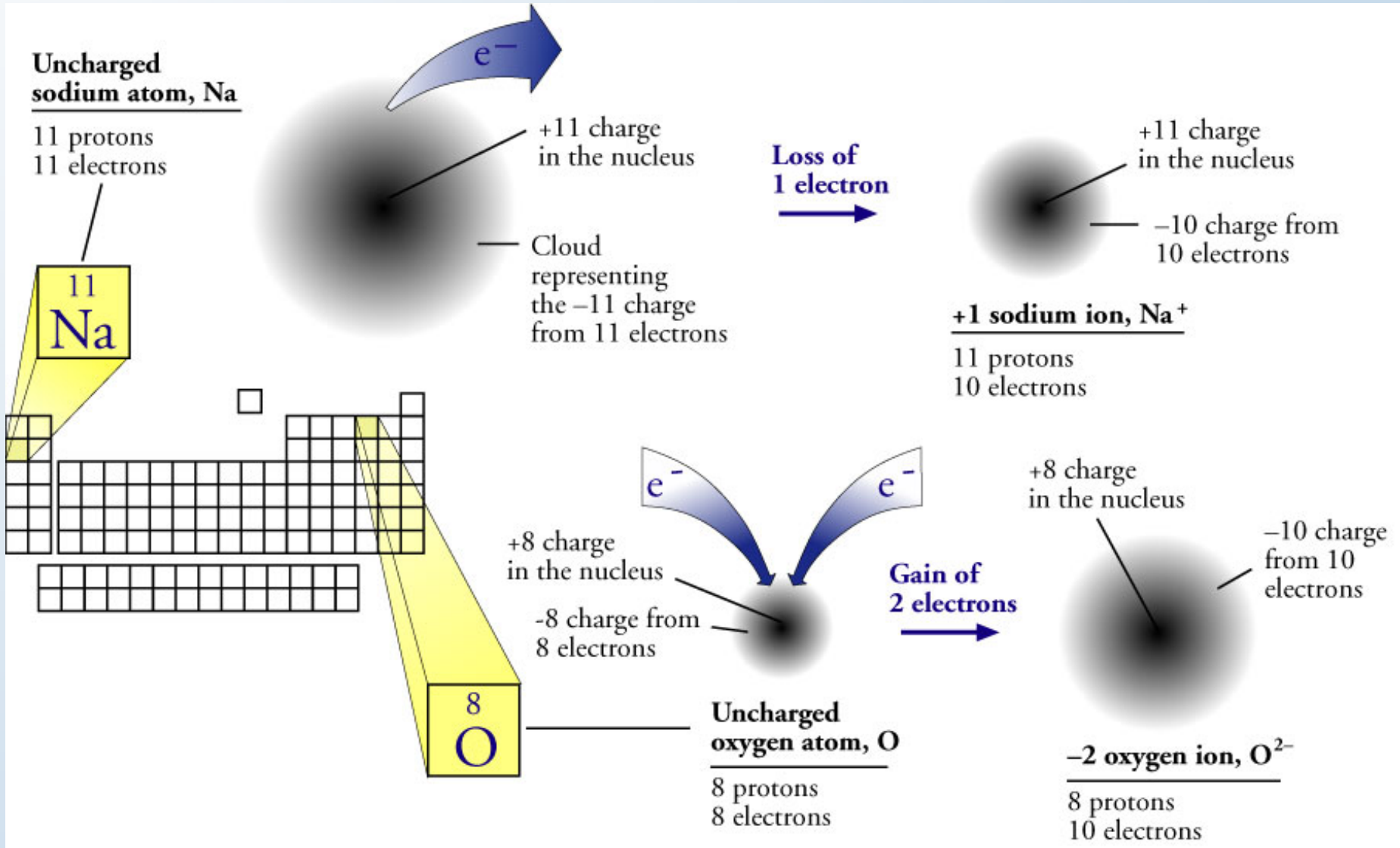
A vertical column of water molecules (H<sub>2</sub>O) is shown on the left side of the slide. Each molecule consists of one large red sphere (oxygen) and two smaller black spheres (hydrogen) bonded together. The molecules are arranged in a descending staircase pattern from the top left towards the bottom left.

# Ions

- ***Ions*** are charged particles due to a loss or gain of electrons.
- When particles lose one or more electrons, leaving them with a positive overall charge, they become ***cations***.
- When particles gain one or more electrons, leaving them with a negative overall charge, they become ***anions***.



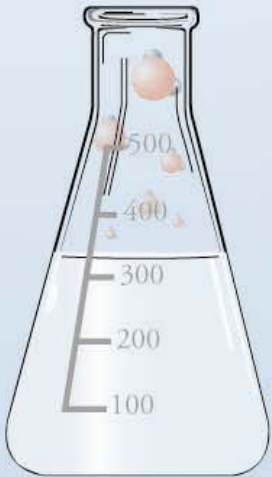
# Example Ions



A decorative border on the left side of the slide consists of several water molecules (H<sub>2</sub>O) arranged in a vertical line. Each molecule is represented by a large red sphere (oxygen) and two smaller black spheres (hydrogen) bonded to it. The molecules are scattered from the top left towards the bottom left, with some appearing to be inside a flask.

# Isotopes

- ***Isotopes*** are atoms with the same atomic number but different mass numbers.
- ***Isotopes*** are atoms with the same number of protons and electrons in the uncharged atom but different numbers of neutrons.
- ***Isotopes*** are atoms of the same element with different masses.



# Isotopes of Hydrogen

All hydrogen atoms have  
1 electron and 1 proton.

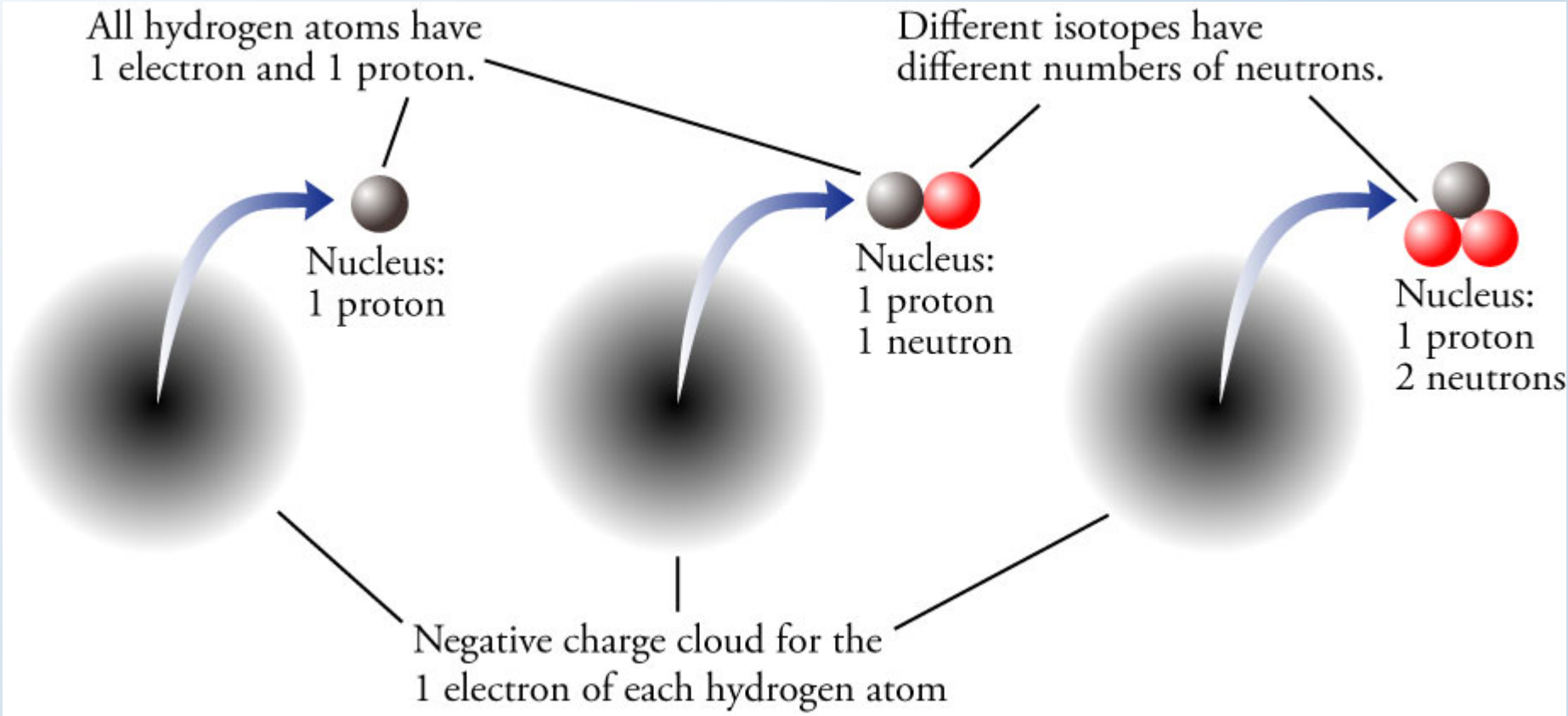
Different isotopes have  
different numbers of neutrons.

Nucleus:  
1 proton

Nucleus:  
1 proton  
1 neutron

Nucleus:  
1 proton  
2 neutrons

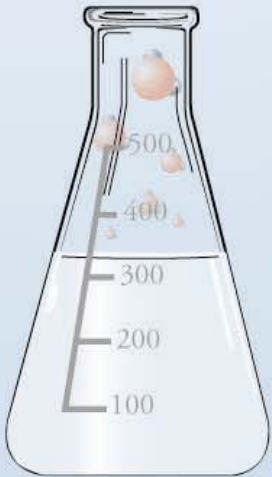
Negative charge cloud for the  
1 electron of each hydrogen atom





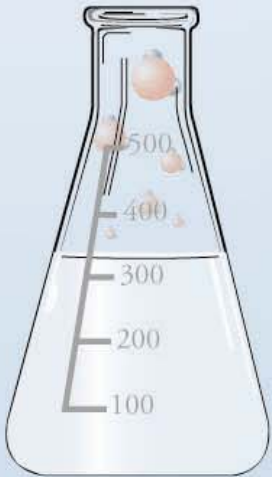
# Possible Discovery of Elements 113 and 115

- Dubna, Russia
- Dubna's Joint Institute for Nuclear Research and Lawrence Livermore National Laboratory
- Bombarded a target enriched in americium,  $^{243}\text{Am}$ , with calcium atoms,  $^{48}\text{Ca}$ .
- From analysis of decay products, they concluded that four atoms of element 115 were created.

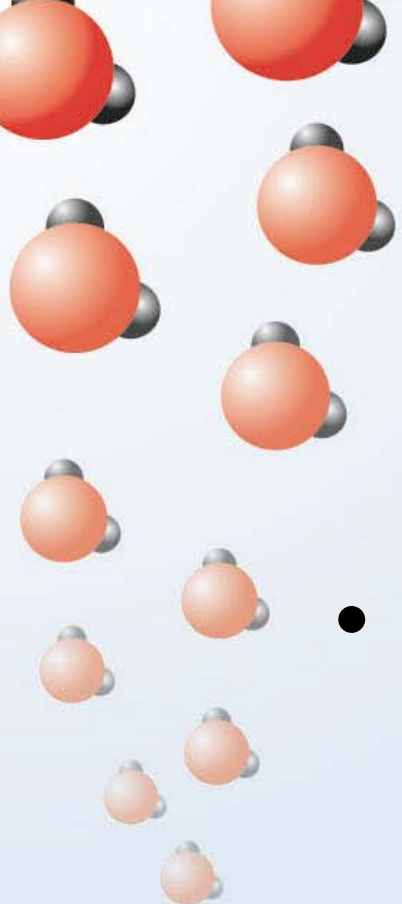


# Elements 113 and 115

- Created  $^{288}115$ , which lasted about 100 milliseconds...a very long time for this large an isotope.
- $^{288}115$  emitted an  $\alpha$ -particle,  $^4\text{He}$ , to form  $^{284}113$ .
- The results need to be confirmed.

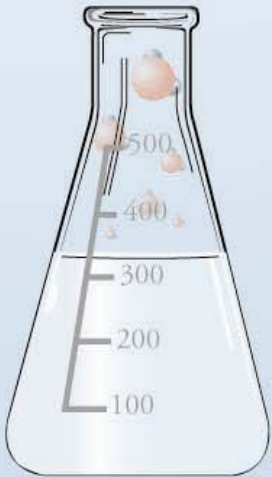






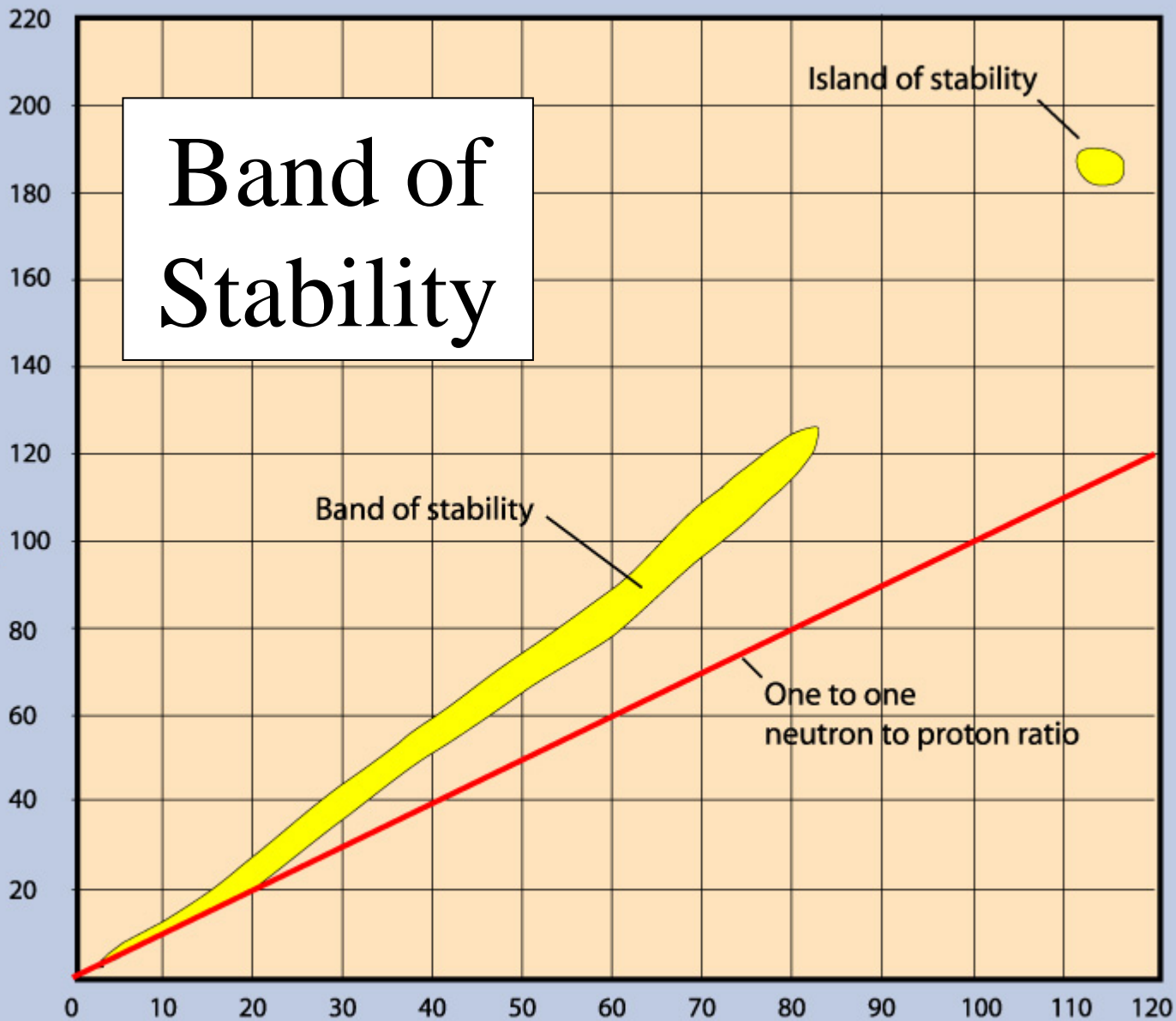
# Why try to make elements that last such a short time?

- To support theories of the nature of matter.
  - The standard model of the nature of matter predicts that elements with roughly 184 neutrons and 114 protons would be fairly stable. (See next slide.)
  - $^{288}_{115}$ , which lasted a relatively long time, has 115 protons and 173 neutrons.



# Band of Stability

Number of neutrons

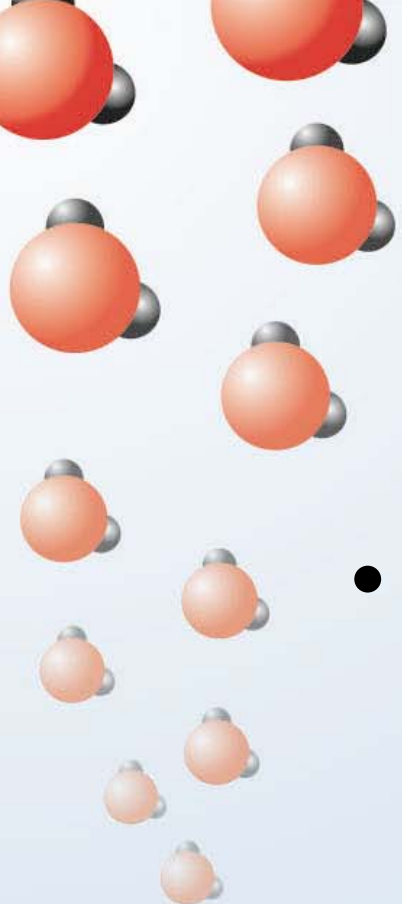


Island of stability

Band of stability

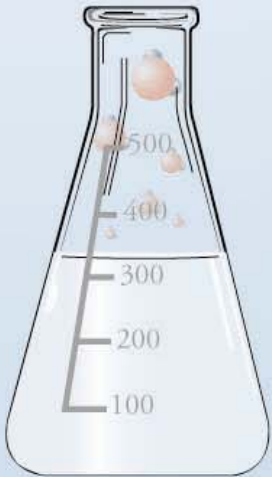
One to one  
neutron to proton ratio

Number of protons



# Why try to make elements that last such a short time? (cont.)

- The technology developed to make new elements is also being used for medical purposes.
  - Heavy-ion therapy as a treatment for inoperable cancers
    - Beams of carbon atoms shot at tumor.
    - Heavier particle beam is less likely to scatter.
    - Releases most of energy at end of path so easier to focus.



A series of water molecules, each consisting of one red oxygen atom and two black hydrogen atoms, are shown falling from the top left towards the bottom left. At the bottom left, a glass Erlenmeyer flask is partially filled with a liquid. The flask has a vertical scale on its left side with markings at 100, 200, 300, 400, and 500. The liquid level is at approximately 350. Several water molecules are shown entering the flask from the top.

# Effect on Chemical Changes

- **Electrons**

- Can be gained, lost, or shared...actively participate in chemical changes
- Affect other atoms through their -1 charge

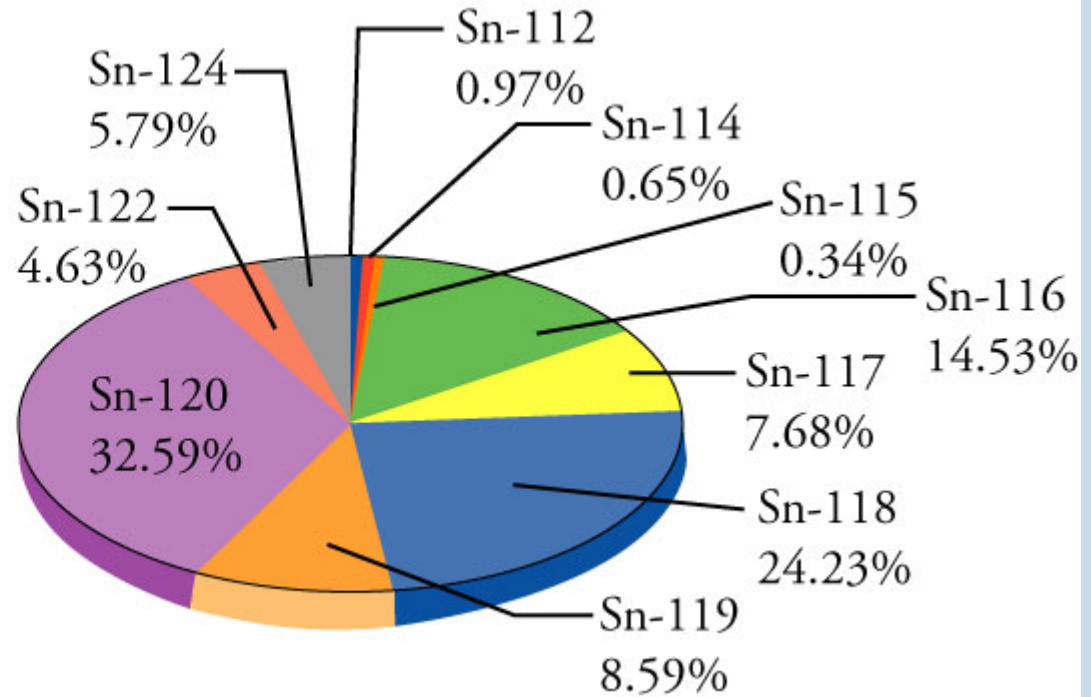
- **Protons**

- Affect other atoms through their +1 charge
- Determine the number of electrons in uncharged atoms

- **Neutrons**

- No charge...no effect outside the atom and no direct effect on the number of electrons.

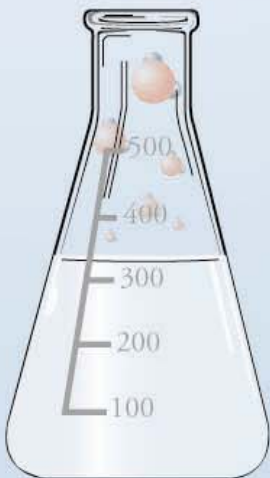
# Tin has ten natural isotopes.





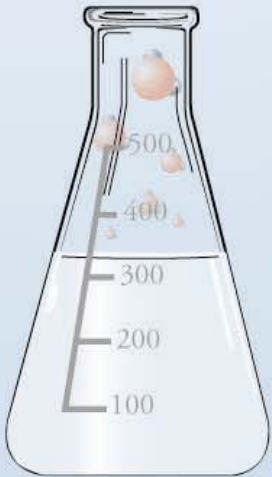
# To Describe Structure of Elements

- What particles?
  - Noble gases – atoms
  - Other nonmetals - molecules
    - Diatomic elements –  $\text{H}_2$ ,  $\text{N}_2$ ,  $\text{O}_2$ ,  $\text{F}_2$ ,  $\text{Cl}_2$ ,  $\text{Br}_2$ ,  $\text{I}_2$
    - $\text{S}_8$ ,  $\text{Se}_8$ ,  $\text{P}_4$
    - C(diamond) huge molecules
  - Metallic elements – cations in a sea of electrons



# To Describe Structure of Elements (2)

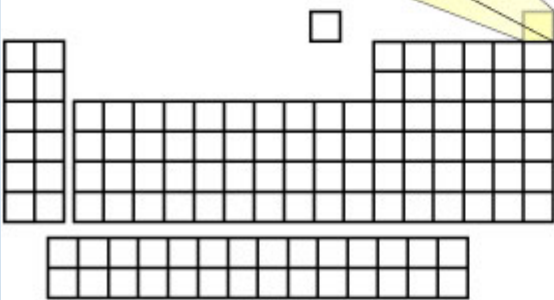
- Solid, liquid, or gas?
  - Gases -  $\text{H}_2$ ,  $\text{N}_2$ ,  $\text{O}_2$ ,  $\text{F}_2$ ,  $\text{Cl}_2$ , He, Ne, Ar, Kr, and Xe
  - Liquids –  $\text{Br}_2$  and Hg
  - Solids – the rest
- Standard description of (1) solid, (2) liquid, (3) gas, or (4) metal.



# Helium Gas, He

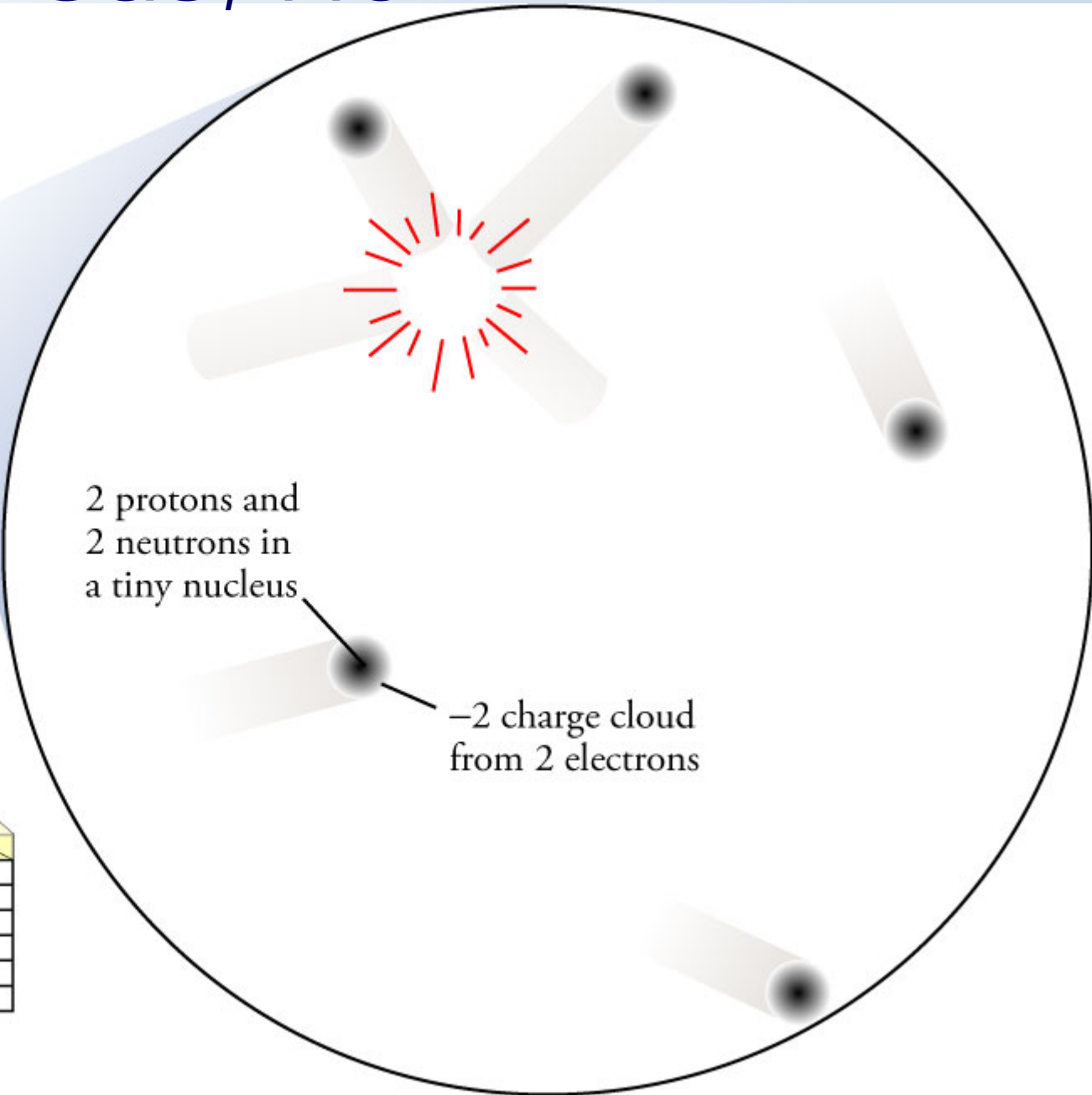


$^2$   
He



2 protons and  
2 neutrons in  
a tiny nucleus

-2 charge cloud  
from 2 electrons

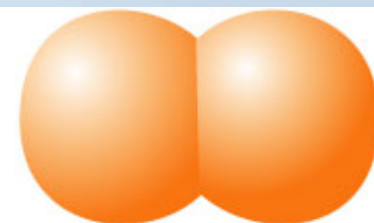




# Hydrogen, H<sub>2</sub>, Molecule

Hydrogen nuclei

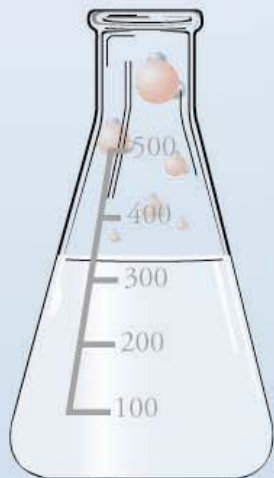
The two electrons  
generate a charge  
cloud surrounding  
both nuclei.



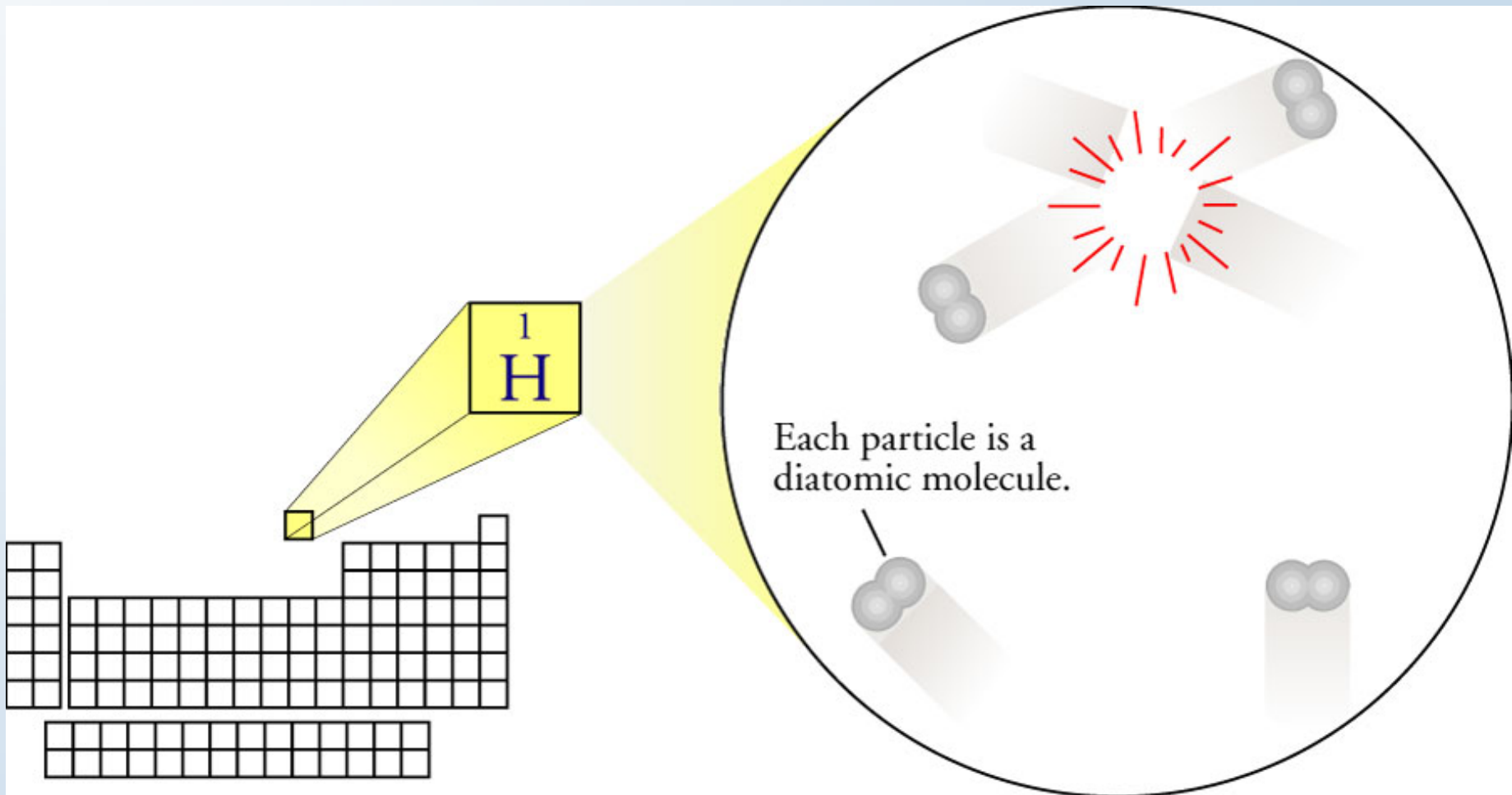
Space-filling model  
Emphasizes  
individual atoms



Ball-and-stick model  
Emphasizes bond



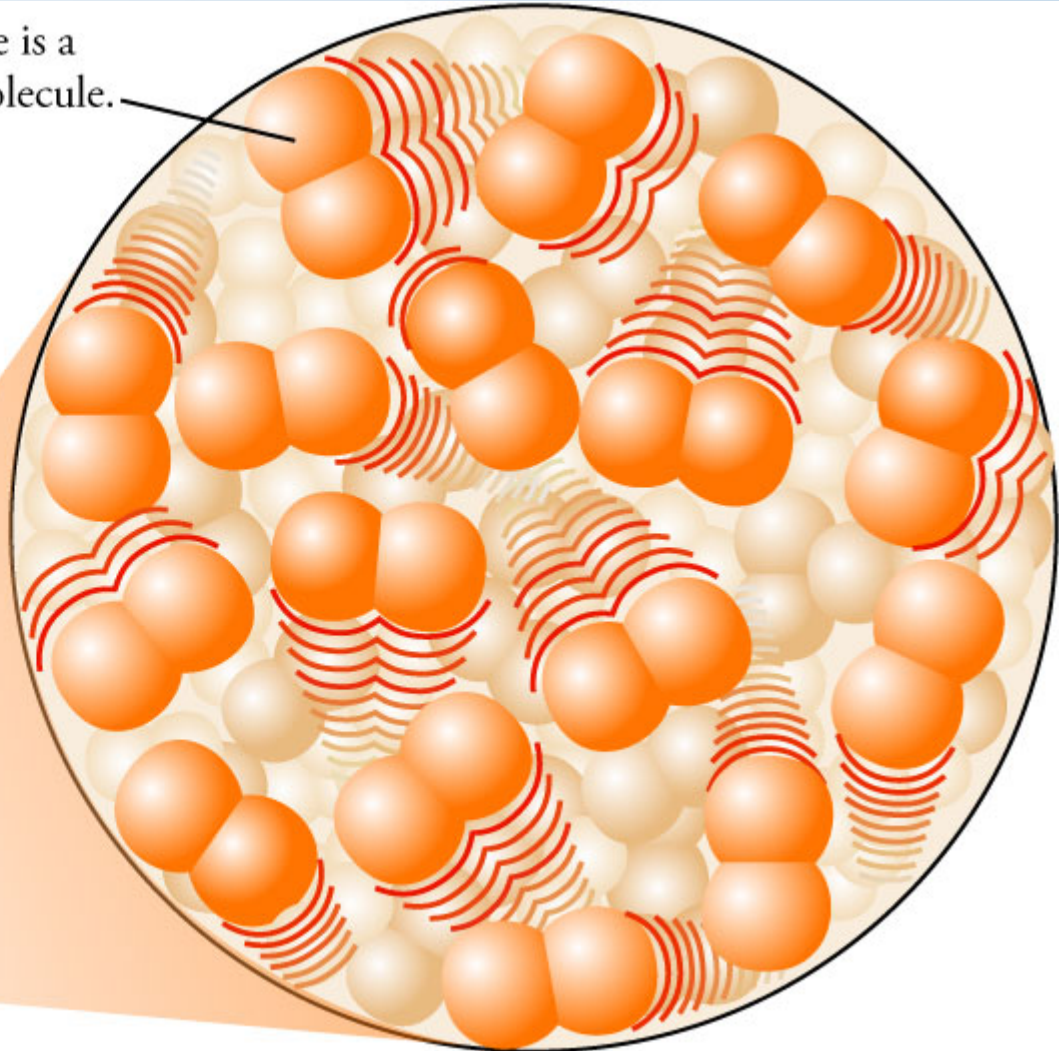
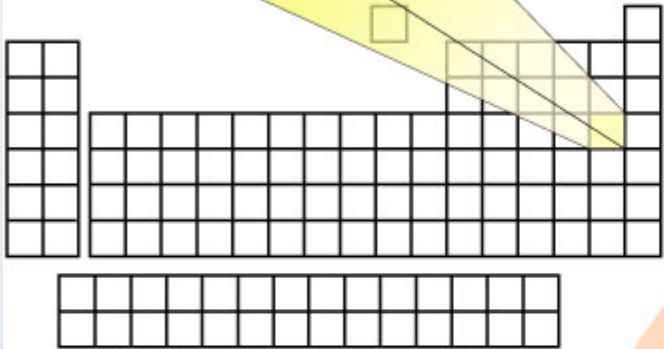
# Hydrogen Gas, H<sub>2</sub>

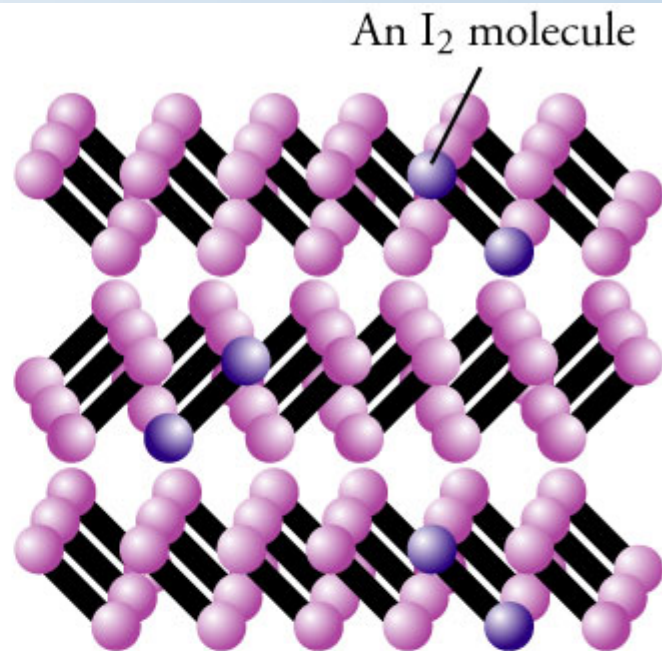
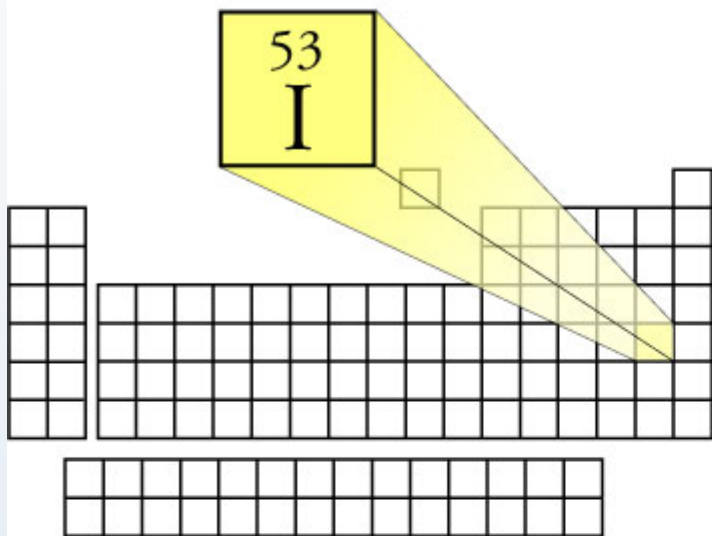


# Bromine Liquid

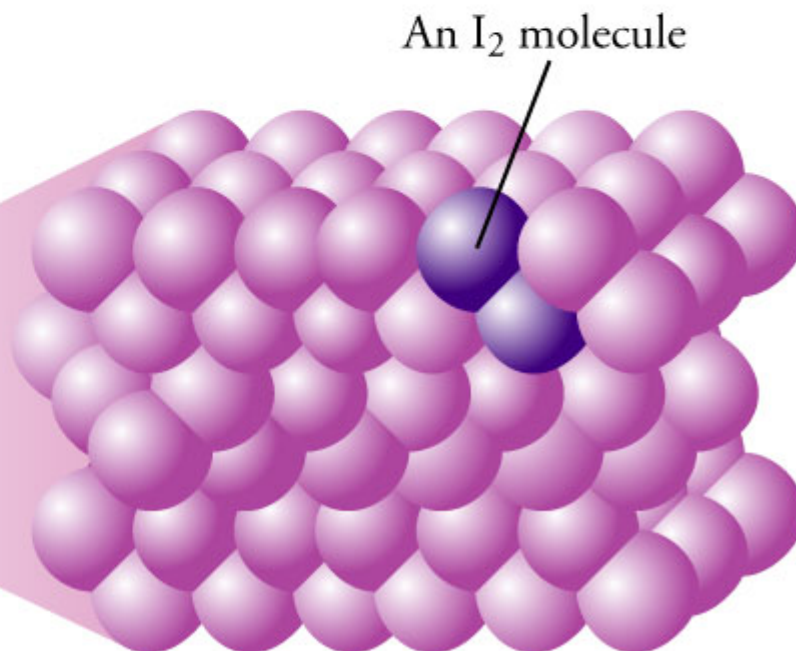
35  
Br

Each particle is a diatomic molecule.

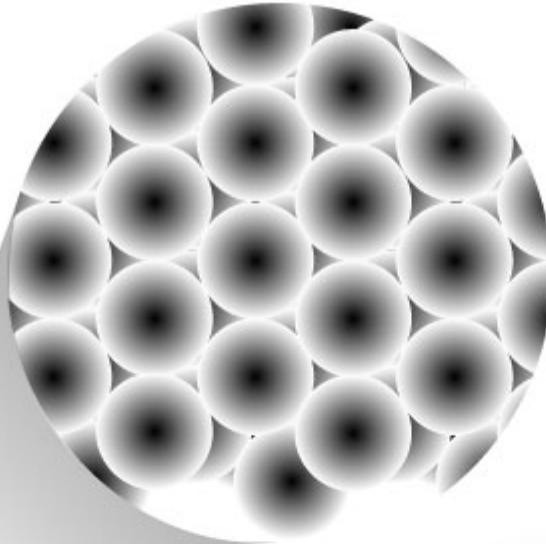




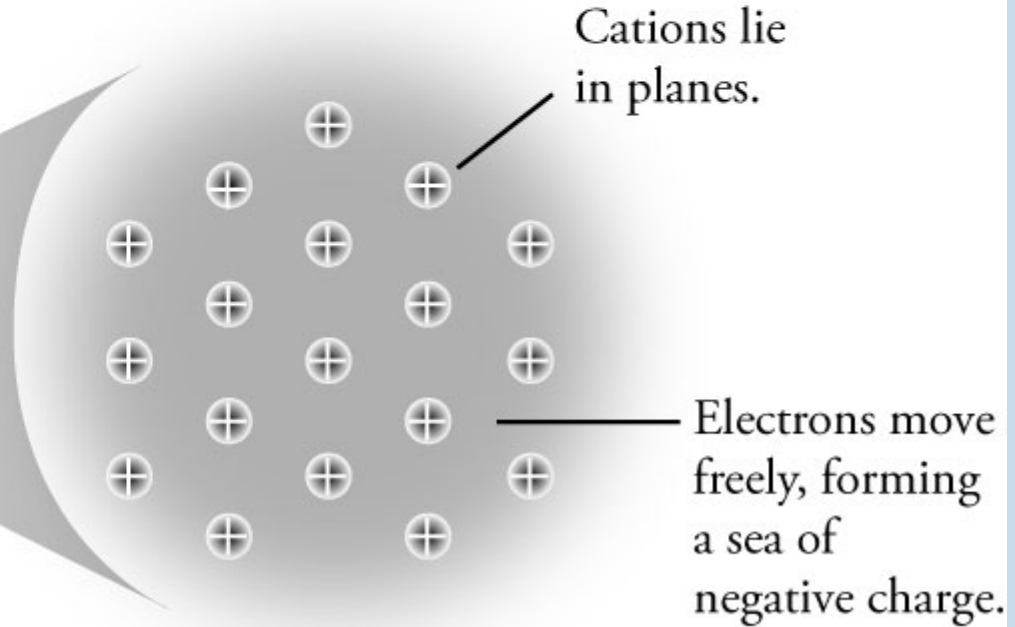
# Iodine Solid



Atoms are packed closely together.



# Typical Metallic Solid and Its "Sea of Electrons"



Sea-of-Electrons Model