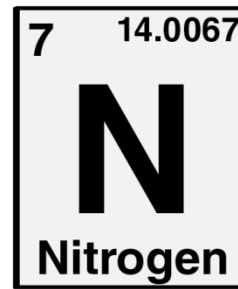
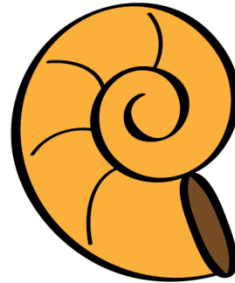
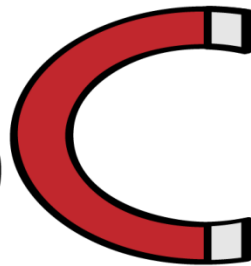
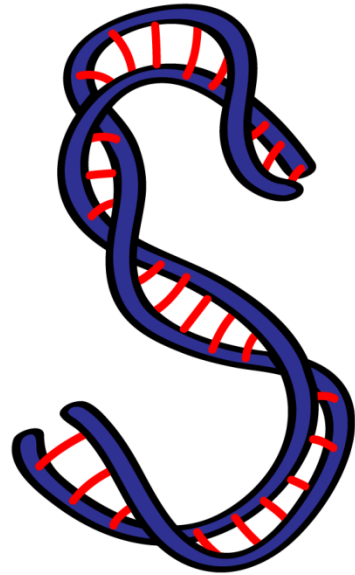


ATOMS, MOLECULES, AND LIGHT

SAYAN BAGCHI
NCL PUNE



Science

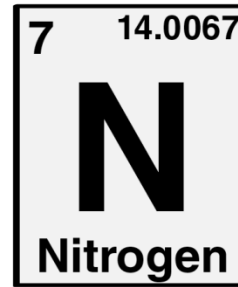
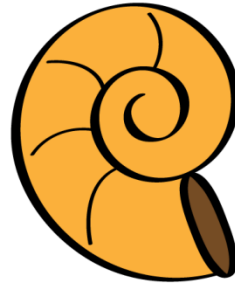
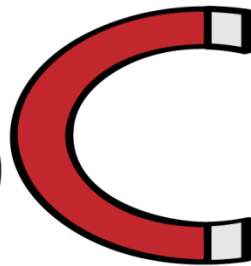
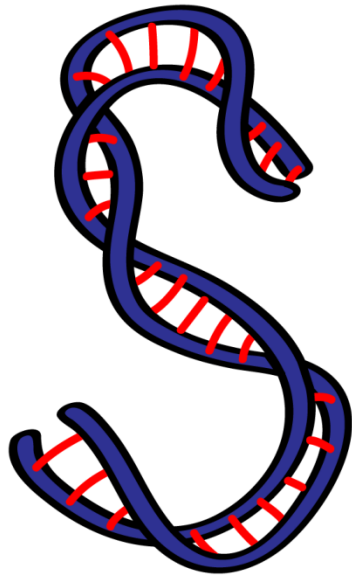
Why?



How?



Chemistry



Science

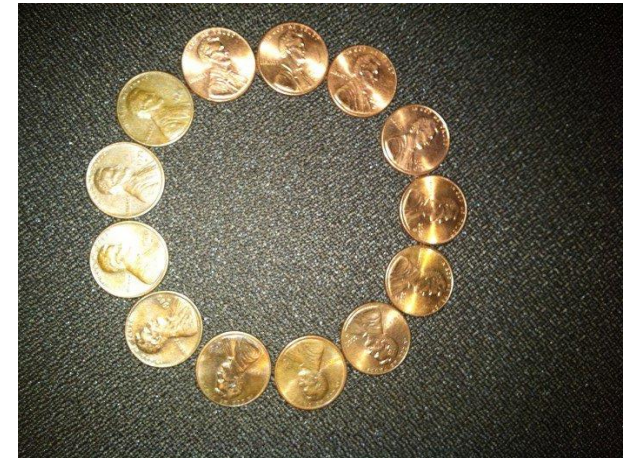
Some metals tarnish over time



Gold



Silver



Copper

Why?

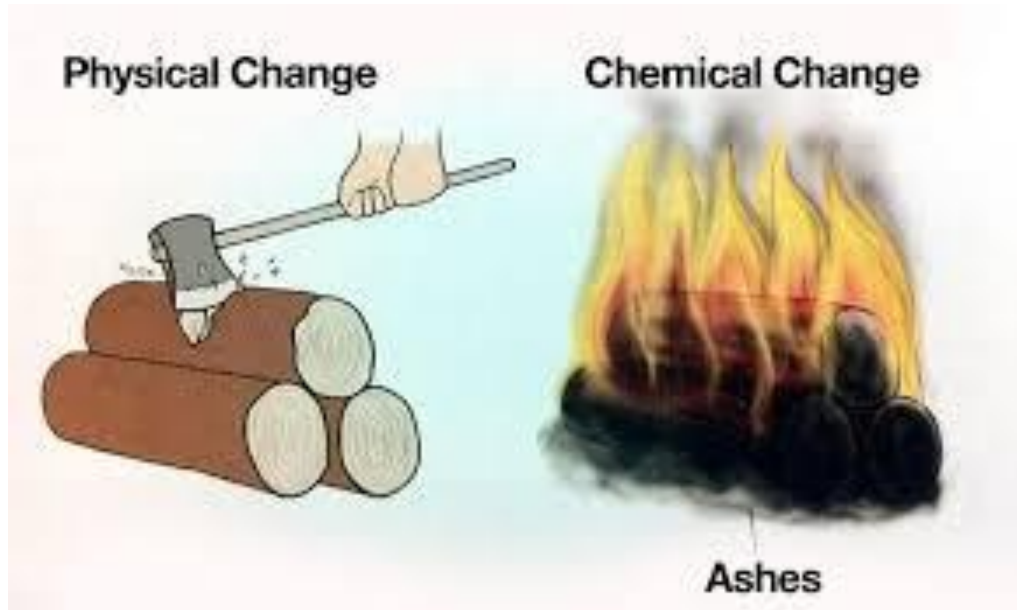
Oxidation

How?

Chemistry: reaction between air and metal

What does chemistry tell us? How things change

Chemical change versus Physical change

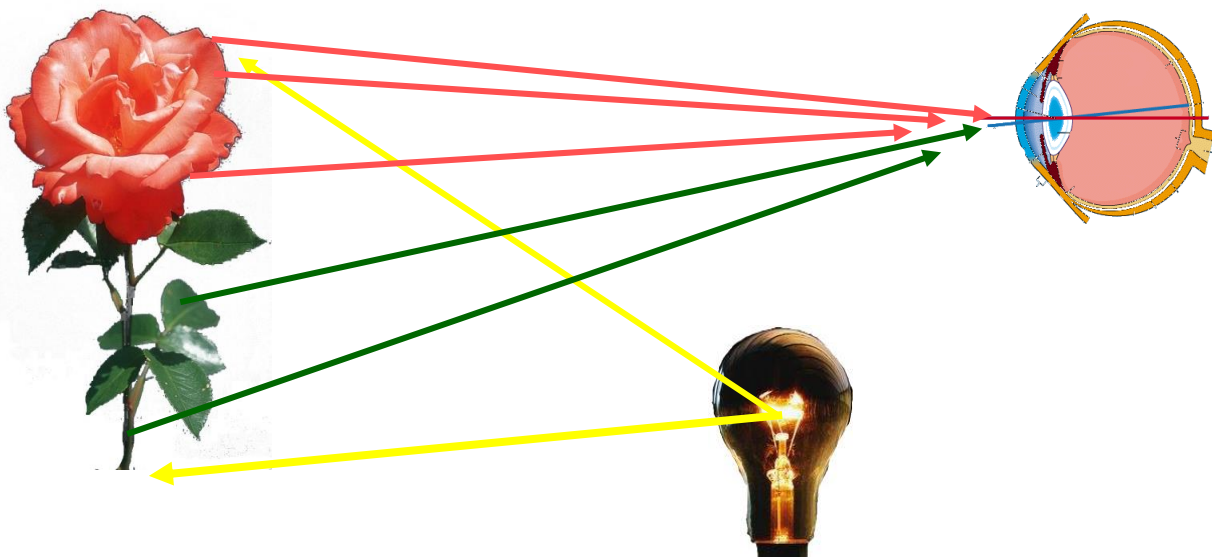


Evidence of Chemical Changes

Clue	Example	Description
Color change	Bread dough baking	Changes from white to brown 
Smell	Eggs rotting	Smells bad 
New matter created	Wood burning	Wood changes to ash 
Gas created	Baking soda added to vinegar	Creates carbon dioxide gas 
Heat or Light created	Fireworks	Burning chemicals create light and heat 

Size of a system

To observe something, must interact with it.
Always true



Light hits flower, "bounces off."
Detect (observe) with eye, camera, etc.



To understand chemical change:
Divide the object/system into smaller objects

Big and Small: Relative Concept

Rocks come in all sizes.



Wrong experiment
Right experiment

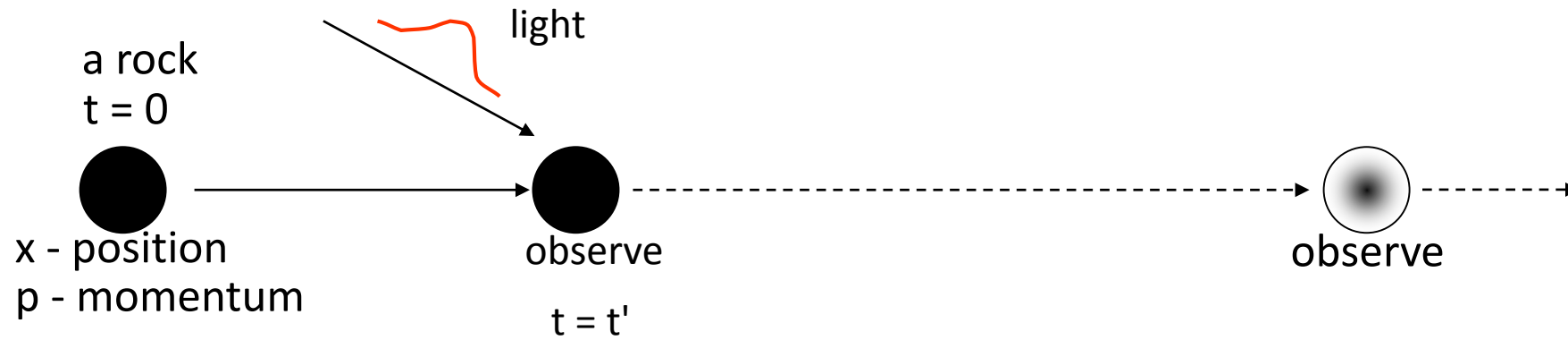


wrong size
right size

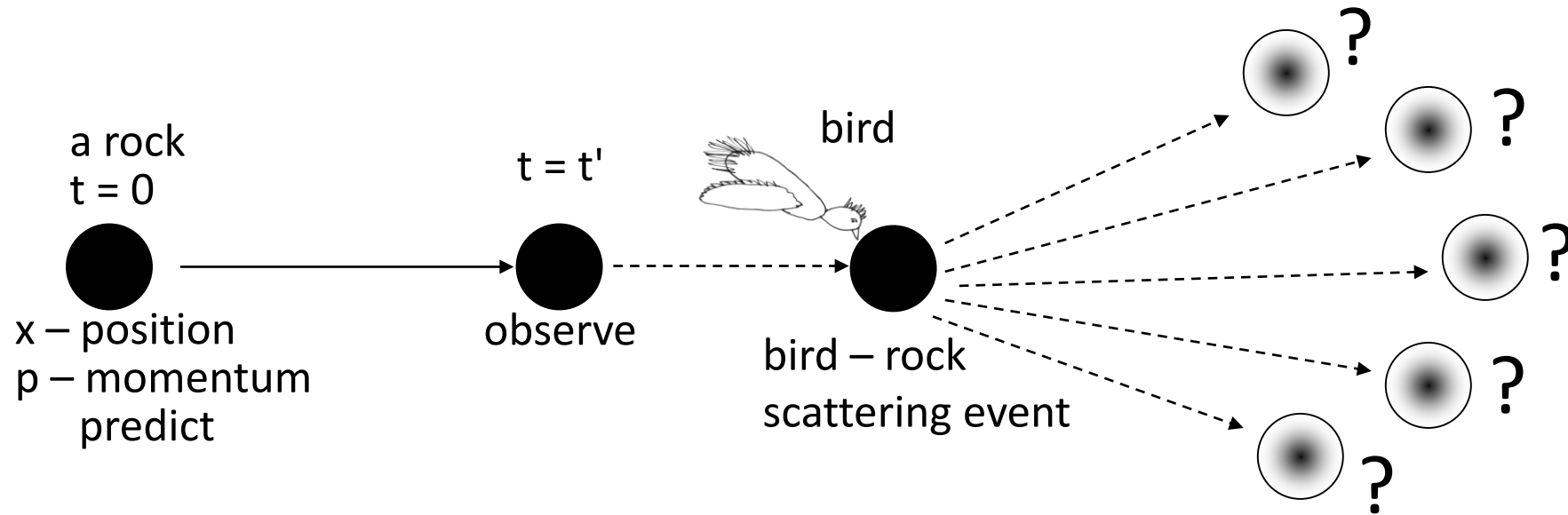
Comparison determines if a rock is big or small.



Implies – **Size is relative.** Size depends on the object and your experimental technique.

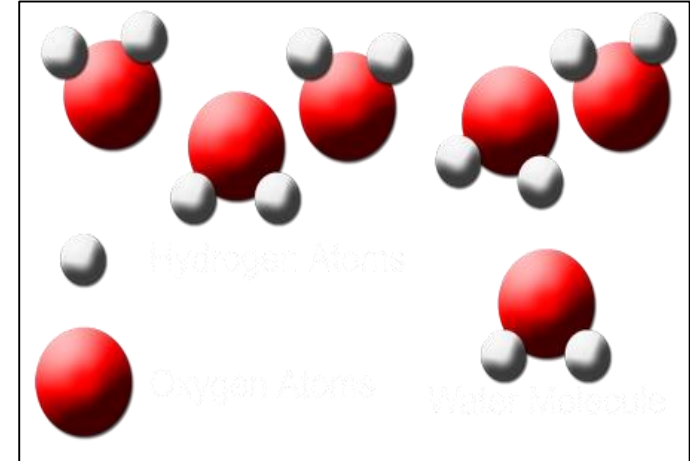
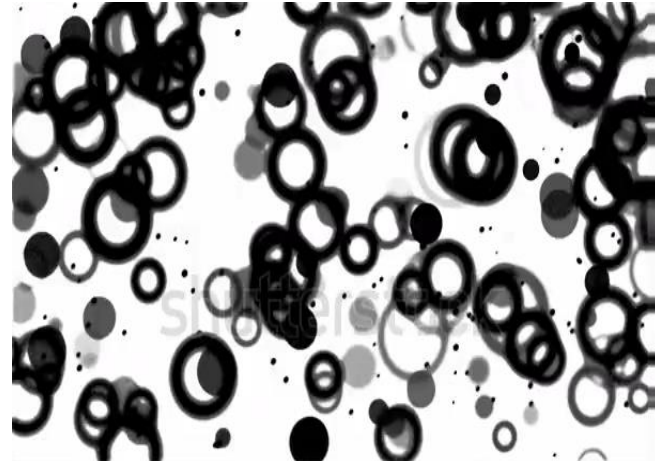


Make observation of trajectory. Predict future location.



Following non-negligible disturbance – don't know outcome.

How small is small?



Disturbance caused by observation (measurement)

negligible

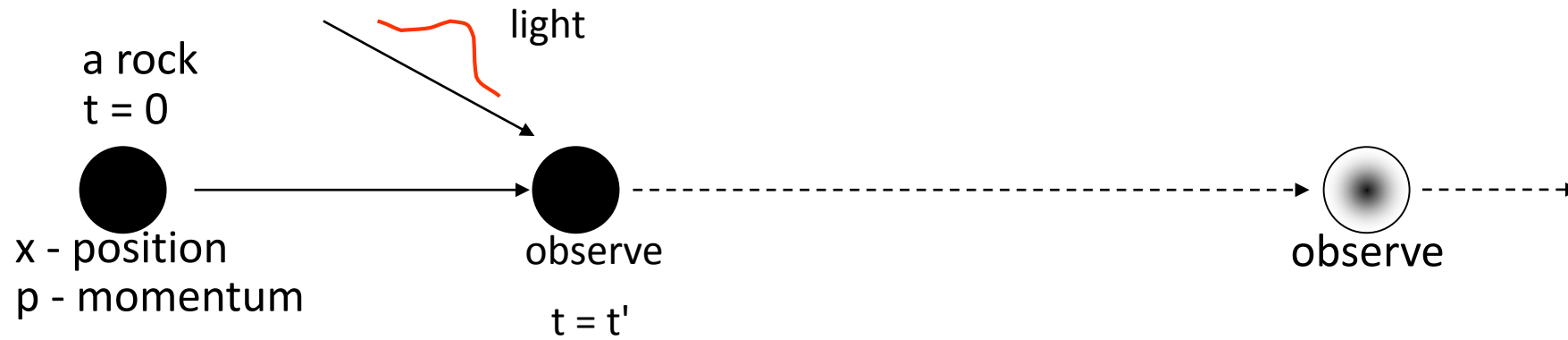


object big

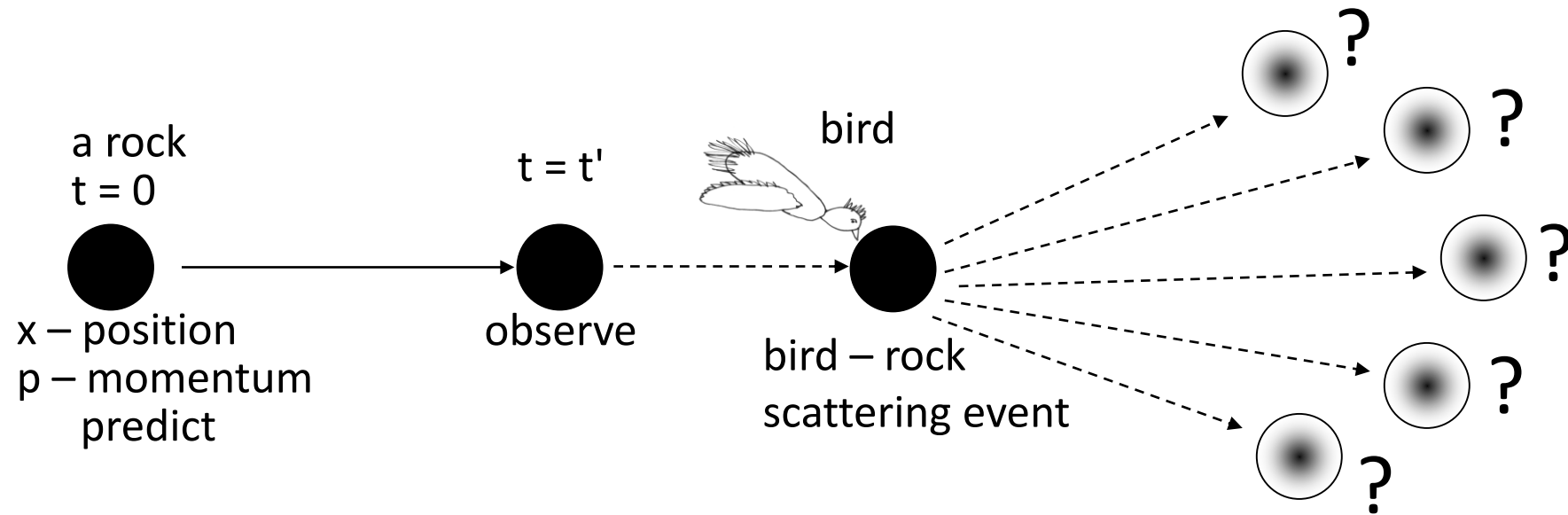
non-negligible



object small



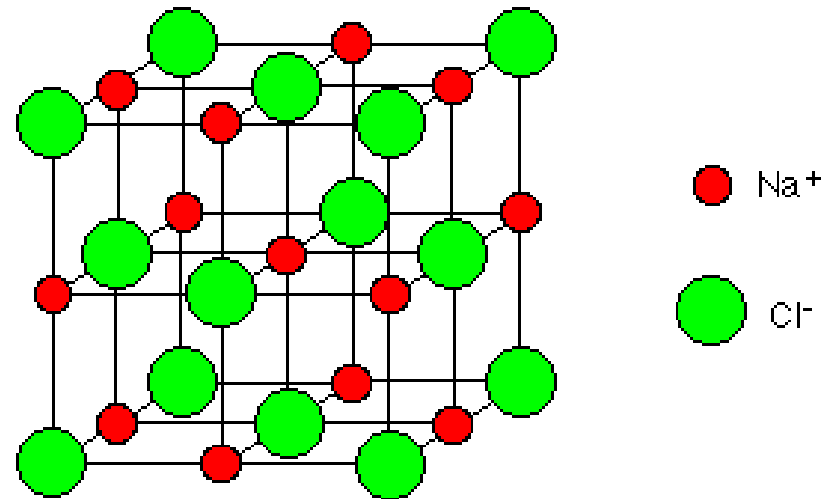
Make observation of trajectory. Predict future location.

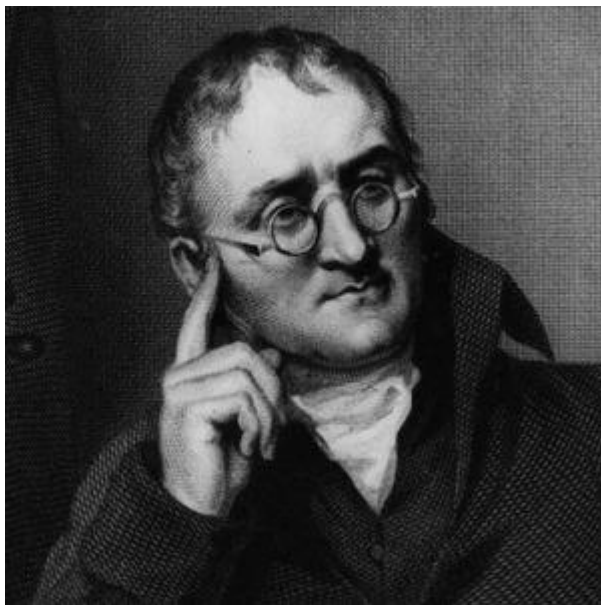


Following non-negligible disturbance – don't know outcome.

Big Objects (matter) consists of smaller objects

Smaller objects consists of even smaller particles





John Dalton (1776 – 1844)

Dalton's Atomic Theory

- 1.) All matter is made up of tiny particles called atoms.
- 2.) All atoms of a given element are alike, but are different from the atoms of any other element.
- 3.) Compounds are formed when atoms of different elements combine in fixed proportions.
- 4.) A chemical reaction involves a rearrangement of atoms, not a change in the atoms themselves.

Periodic Table of Elements

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H Hydrogen 1.00794																	2 He Helium 4.002602
2 Li Lithium 6.941	3 Be Beryllium 9.012182											4 B Boron 10.811	5 C Carbon 12.011	6 N Nitrogen 14.007	7 O Oxygen 15.999	8 F Fluorine 18.998	9 Ne Neon 20.180
3 Na Sodium 22.990	4 Mg Magnesium 24.305											13 Al Aluminum 26.982	14 Si Silicon 28.086	15 P Phosphorus 30.974	16 S Sulfur 32.06	17 Cl Chlorine 35.45	18 Ar Argon 39.948
4 K Potassium 39.098	5 Ca Calcium 40.078	6 Sc Scandium 44.956	7 Ti Titanium 47.88	8 V Vanadium 50.942	9 Cr Chromium 52.004	10 Mn Manganese 54.938	11 Fe Iron 55.845	12 Co Cobalt 58.933	13 Ni Nickel 58.693	14 Cu Copper 63.546	15 Zn Zinc 65.38	16 Ga Gallium 69.723	17 Ge Germanium 72.64	18 As Arsenic 74.922	19 Se Selenium 78.96	20 Br Bromine 79.904	21 Kr Krypton 83.80
5 Rb Rubidium 85.468	6 Sr Strontium 87.62	7 Y Yttrium 88.906	8 Zr Zirconium 91.224	9 Nb Niobium 92.906	10 Mo Molybdenum 95.94	11 Tc Technetium (98.906)	12 Ru Ruthenium 101.07	13 Rh Rhodium 102.91	14 Pd Palladium 106.37	15 Ag Silver 107.87	16 Cd Cadmium 112.41	17 In Indium 114.82	18 Sn Tin 118.71	19 Sb Antimony 121.76	20 Te Tellurium 127.6	21 I Iodine 126.91	22 Xe Xenon 131.29
6 Cs Cesium 132.91	7 Ba Barium 137.33	8 La Lanthanum (138.91)	9 Ce Cerium (140.12)	10 Pr Praseodymium (140.91)	11 Nd Neodymium (144.24)	12 Pm Promethium (144.91)	13 Sm Samarium (150.36)	14 Eu Europium (151.96)	15 Gd Gadolinium (157.25)	16 Tb Terbium (158.93)	17 Dy Dysprosium (162.50)	18 Ho Holmium (164.93)	19 Er Erbium (167.26)	20 Tm Thulium (168.93)	21 Yb Ytterbium (173.05)	22 Lu Lutetium (174.96)	
7 Fr Francium (223)	8 Ra Radium (226)	9 Ac Actinium (227)	10 Th Thorium (232)	11 Pa Protactinium (231)	12 U Uranium (238)	13 Np Neptunium (237)	14 Pu Plutonium (244)	15 Am Americium (243)	16 Cm Curium (247)	17 Bk Berkelium (247)	18 Cf Californium (251)	19 Es Einsteinium (252)	20 Fm Fermium (257)	21 Md Mendelevium (258)	22 No Nobelium (259)	23 Lr Lawrencium (260)	

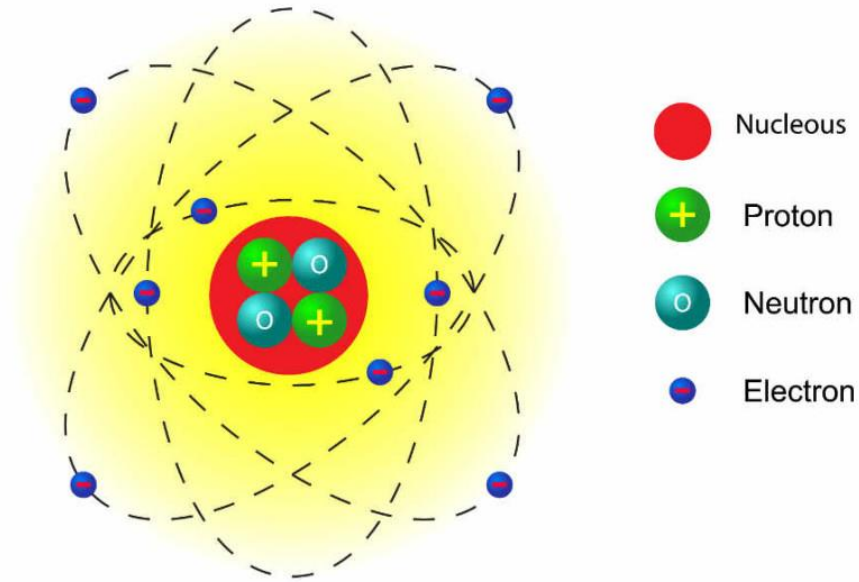
For elements with no stable isotopes, the mass number of the isotope with the longest half-life is in parentheses.

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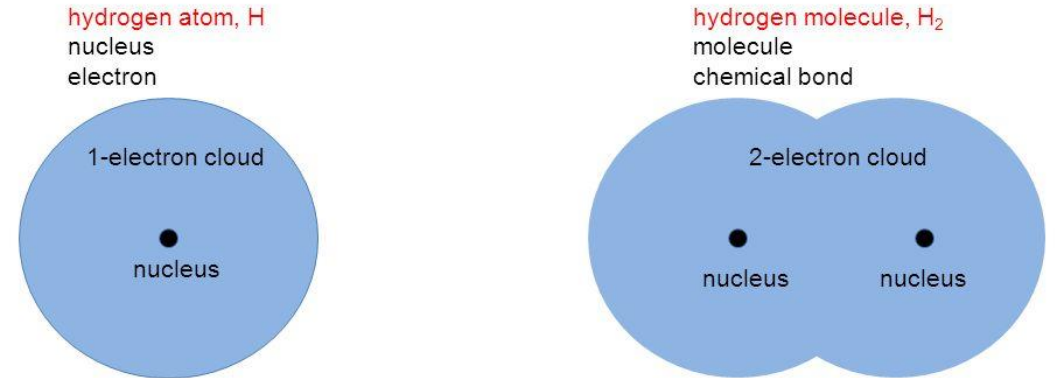
Matter consists of molecules

Molecules consist of atoms

Atoms are further divisible



Atom, molecule, and chemical bond



Can I find the exact position of the electron?

Heisenberg's uncertainty principle:

You can never simultaneously know the exact position and the exact speed of an object

Heisenberg Uncertainty Principle



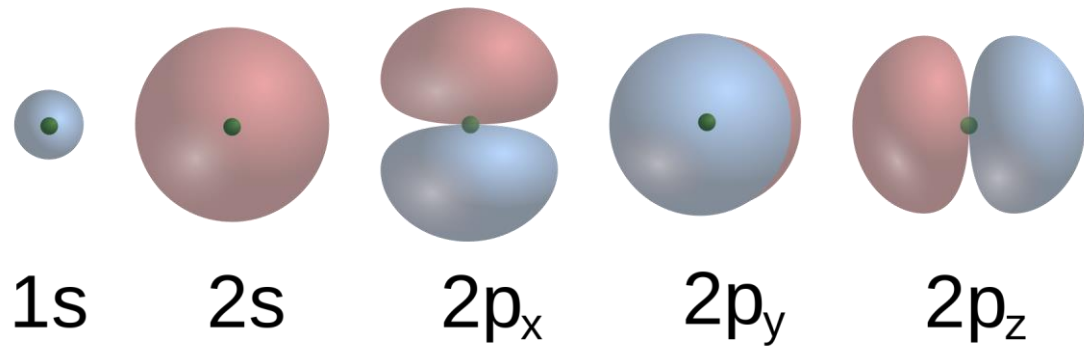
Werner
Heisenberg

"One cannot simultaneously determine both the position and momentum of an electron."

The more certain you are about where the electron is, the less certain you can be about where it is going.

The more certain you are about where the electron is going, the less certain you can be about where it is.

Probable location of electron: Orbital



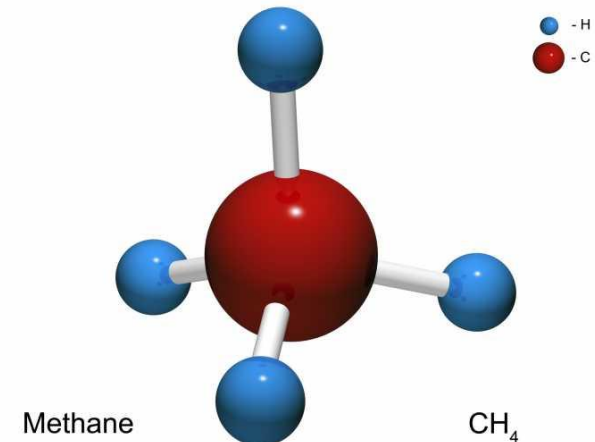
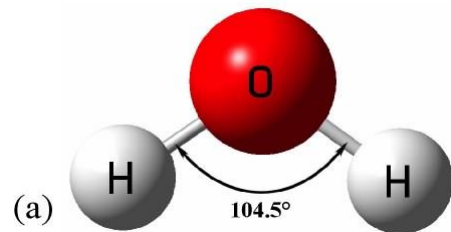
Chemical reaction:

Electrons (orbitals) are meeting first

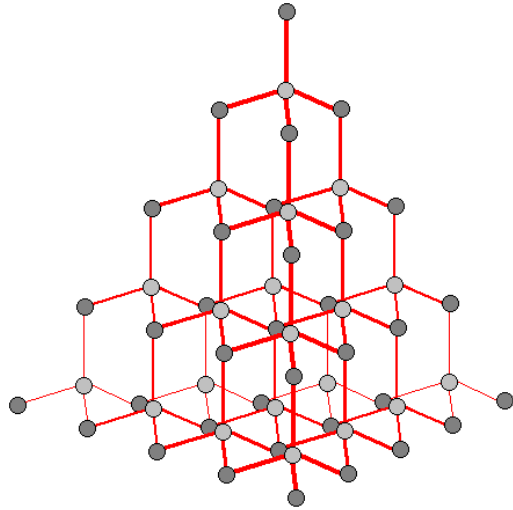
Orbitals have directional property

Reaction will happen in a direction

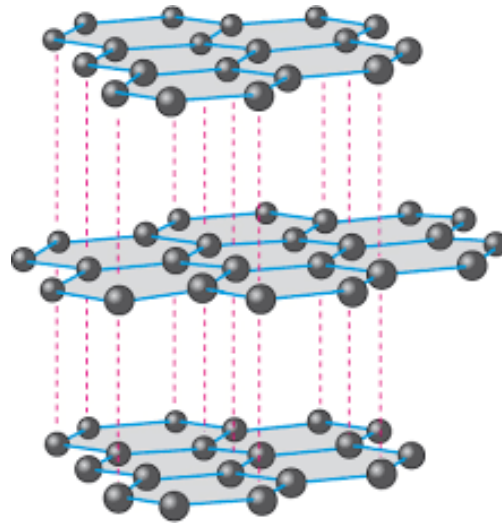
Compounds form will have a unique structure



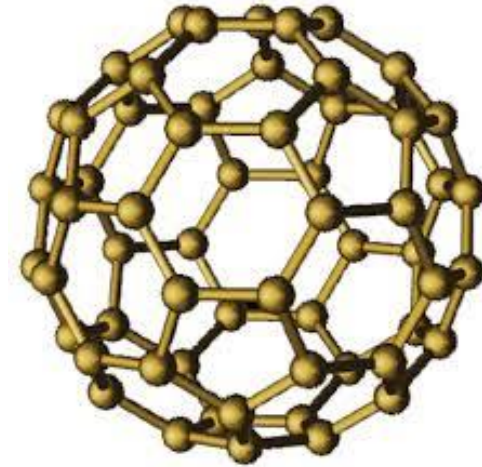
Carbon compounds



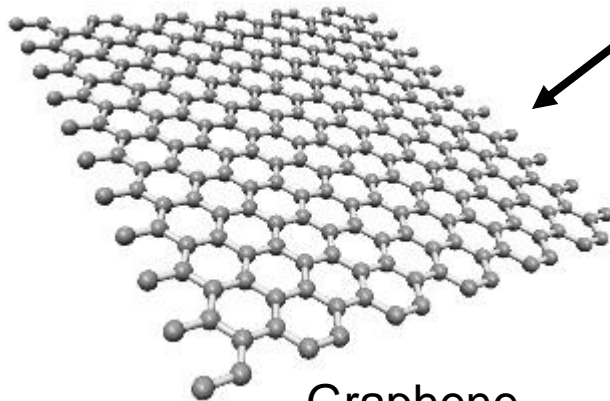
Diamond



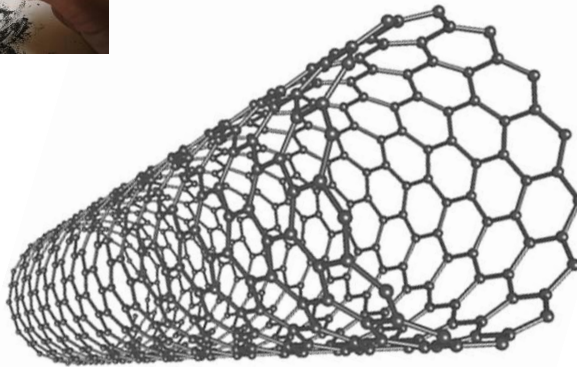
Graphite



Fullerene

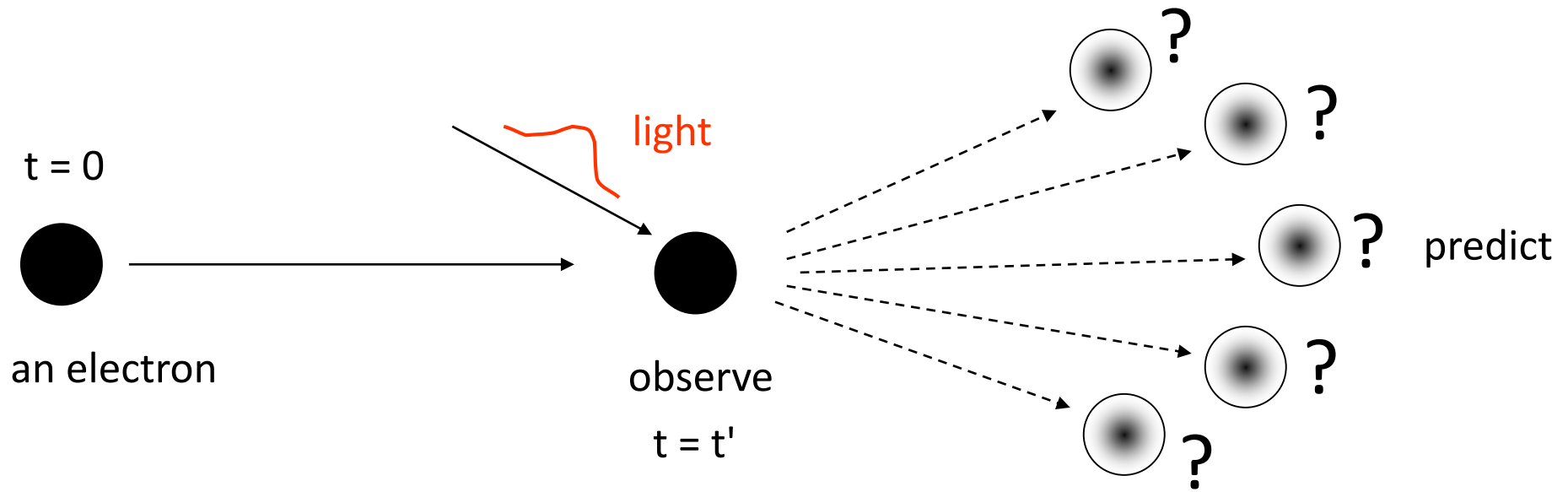


Graphene

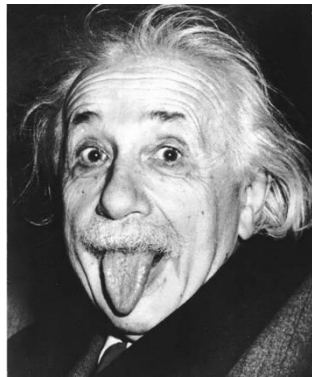


Carbon nanotube





Photon – Electron scattering. **Non-negligible disturbance.**
Can't predict trajectory after observation.



Albert Einstein
 (1879-1955)

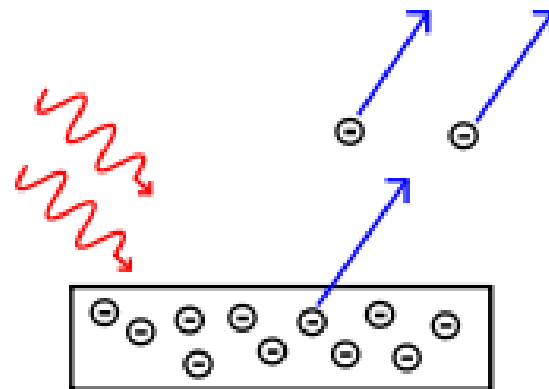
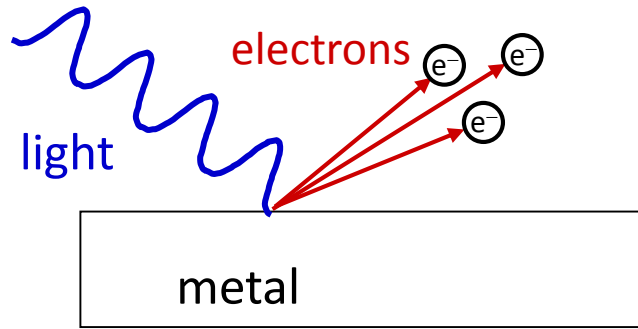


Photo-electric effect

Can we divide light into smaller particles?

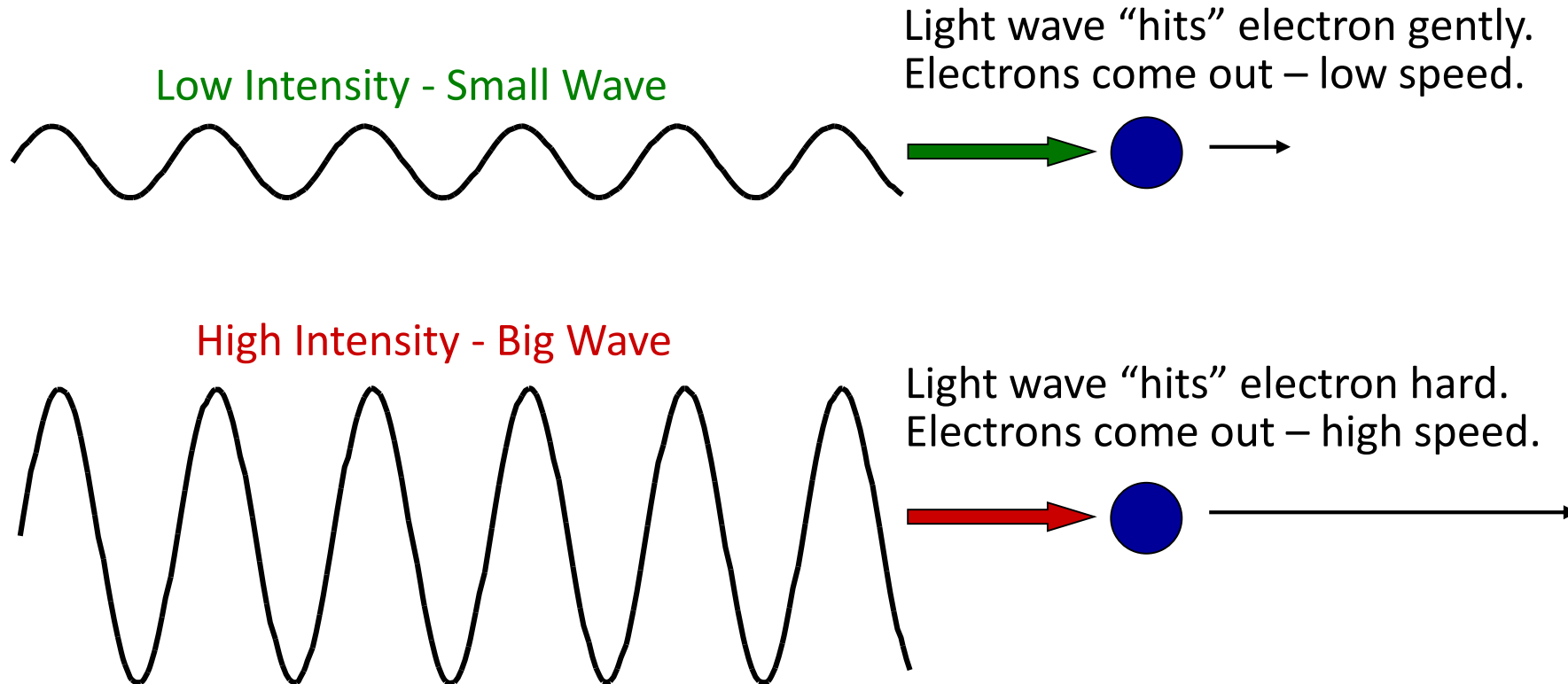
Photo-electric Effect – Classical Theory – Light is a wave.



Experimental results

Shine light of one color on metal –
electrons come out with a certain speed.

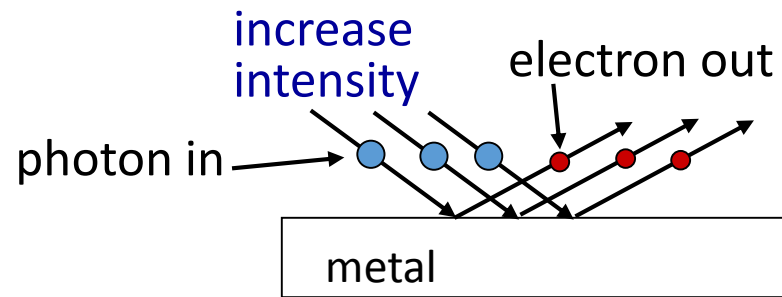
Increase light intensity
get more electrons out with identical speed.



Can we divide light into smaller particles?

Light is composed of small particles

Einstein said “Quanta”



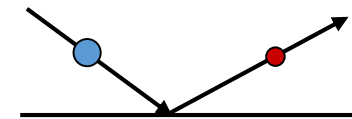
One photon hits one electron.

Increase intensity – more photons,
more electrons hit – more come out.

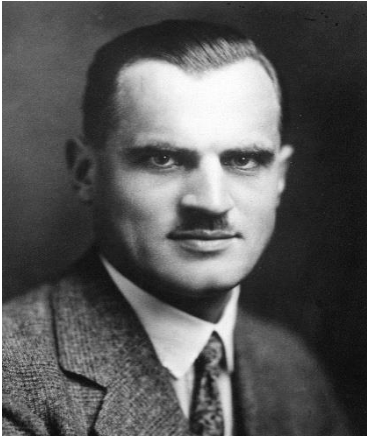
Each photon hits an electron with same impact
whether there are many or few.

Therefore, electrons come out with same speed
independent of the intensity.

Very low energy light, energy too low to overcome binding energy.



There was a huge debate. No experiment could prove it!

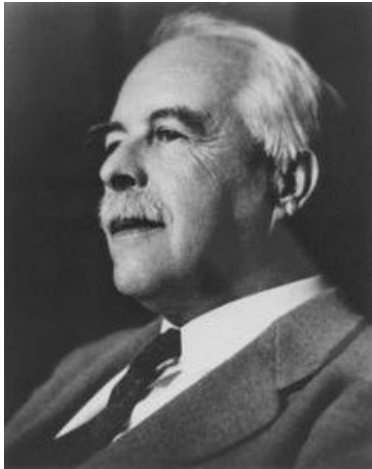


Arthur Compton
1892-1962

Compton effect

Scattering of x-rays from electrons in a carbon target
and found scattered x-rays with a smaller energy than those incident upon the target

First experiment to prove that light is composed of small particles



G. N. Lewis
1875-1946

Came up with a name for the small light particles

Photon

Chemical reaction

Hydrogen atom + Hydrogen atom = Hydrogen molecules (H+H=H₂)
Atom + Atom = Molecule

Hydrogen molecule + Chlorine molecule = Hydrogen chloride
Molecule + Molecule = Molecule

Can these happen?

light + molecule = molecule

molecule 1 + light 1 = molecule 2 + light 2

molecule 1 + molecule 2 = light

light 1 + light 2 = light 3

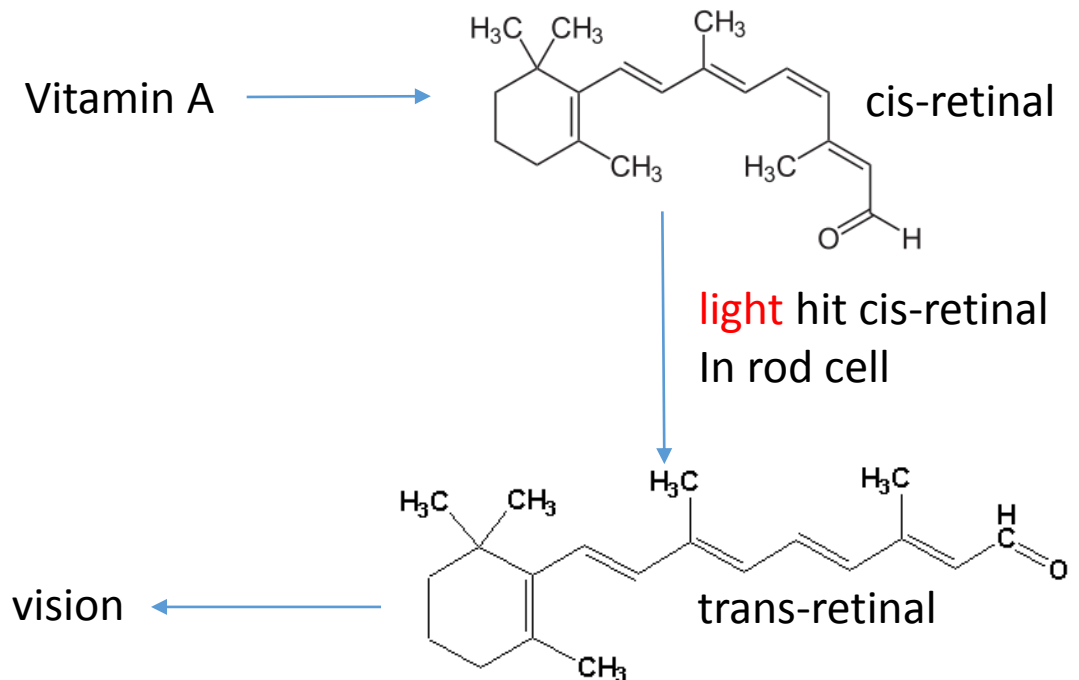
light + molecule 1 = molecule 2

Photochemistry: Light interacts with a molecule to change the molecule to another molecules

Chemistry of Vision

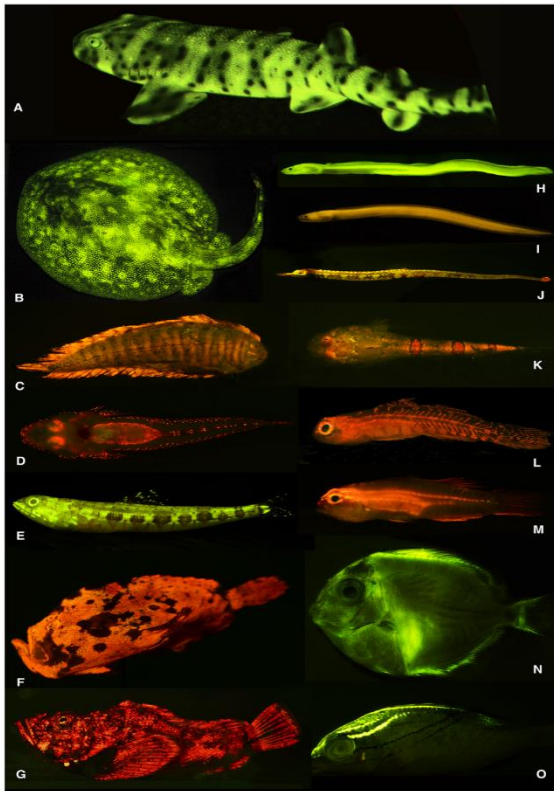


Retina: has rod and cone cells



molecule 1 + light 1 = molecule 2 + light 2

Fluorescence



Marine Fish

Fluorescence is faster than phosphorescence

Phosphorescence



Jelly Fish

molecule 1 + molecule 2 = light 2

Chemiluminescence

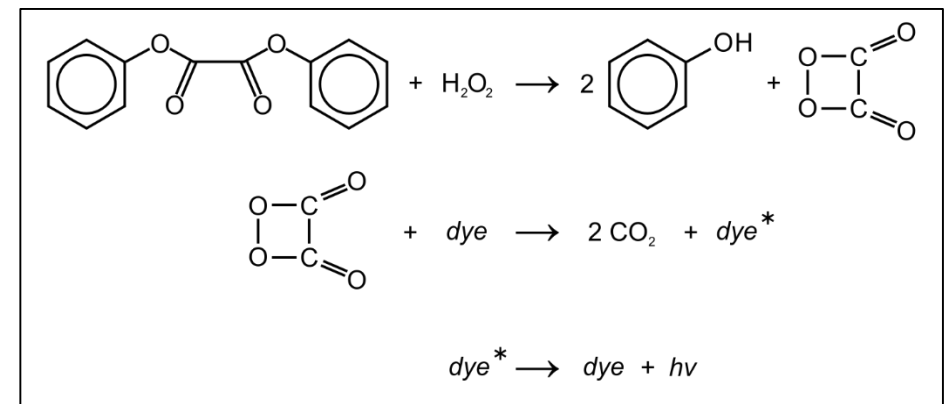
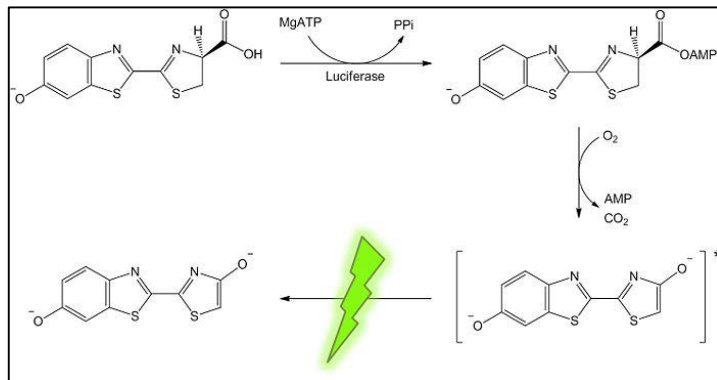
Emission of light as a result of a chemical reaction



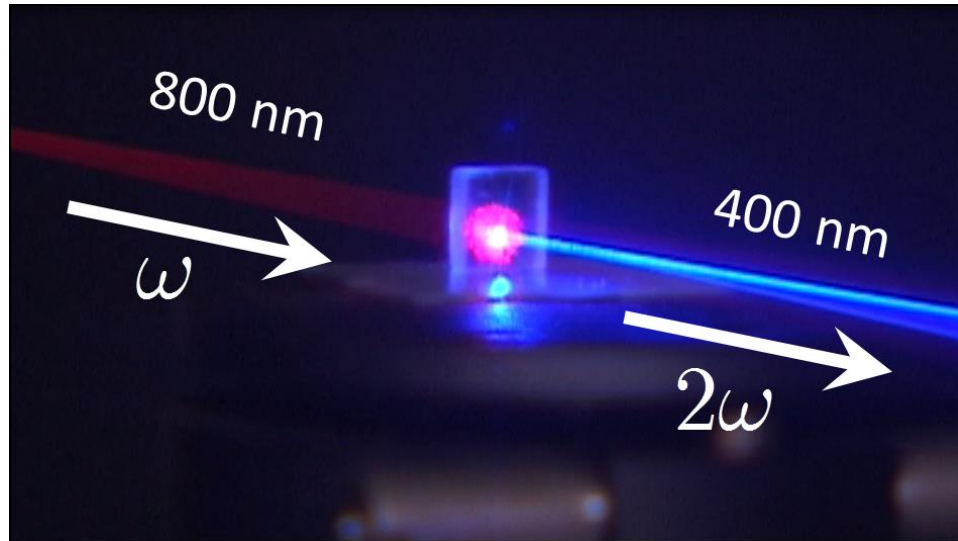
Firefly



Glow stick



light + light = light



Second Harmonic Generation

- 2 lights combine to give a different color light
- Needs a medium which is unchanged

Conclusion

- Big and small are relative
- Absolutely small
- Matter can be divided into atoms and molecules, which can be further divided
- Light is composed of photons
- Interplay between light and atoms and molecules

