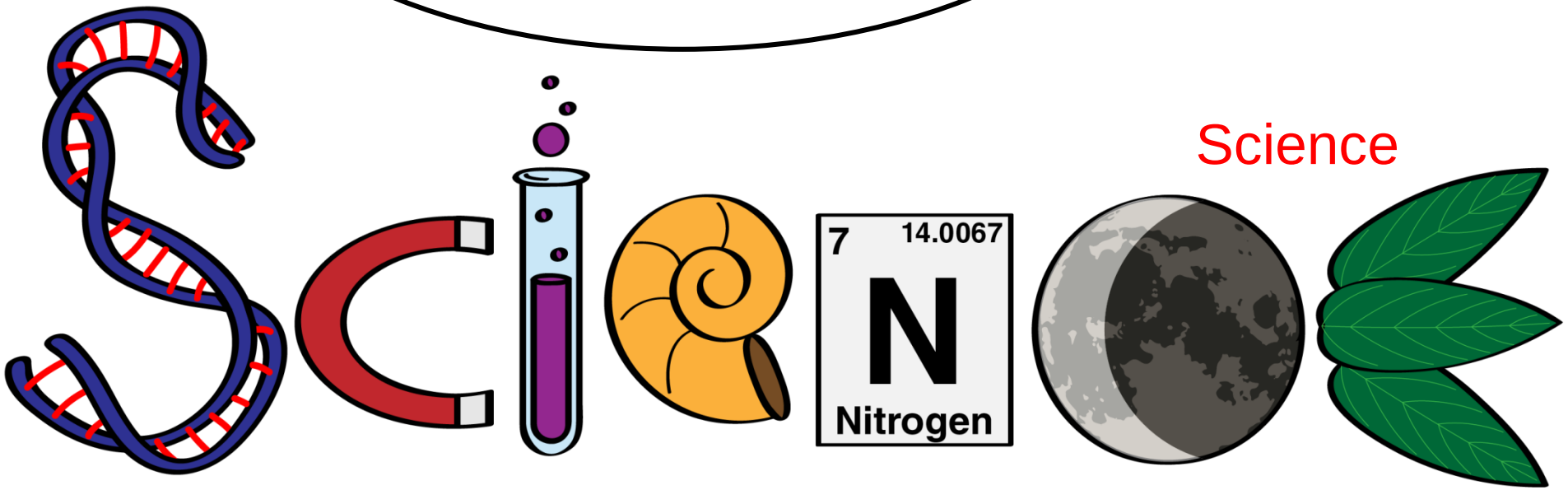
ATOMS, MOLECULES, AND LIGHT

SAYAN BAGCHI
NCL PUNE

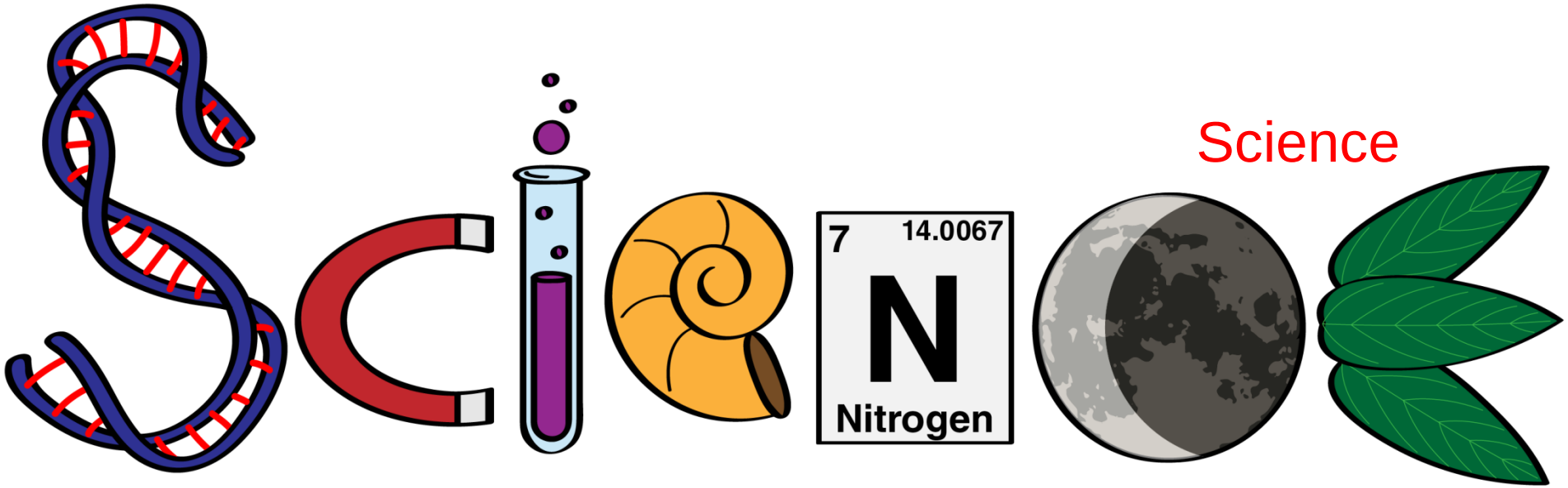


Science

Why?

How?

Chemistry

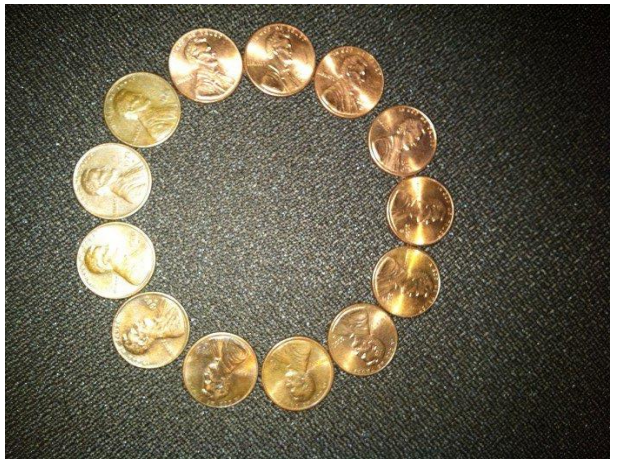


Science

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

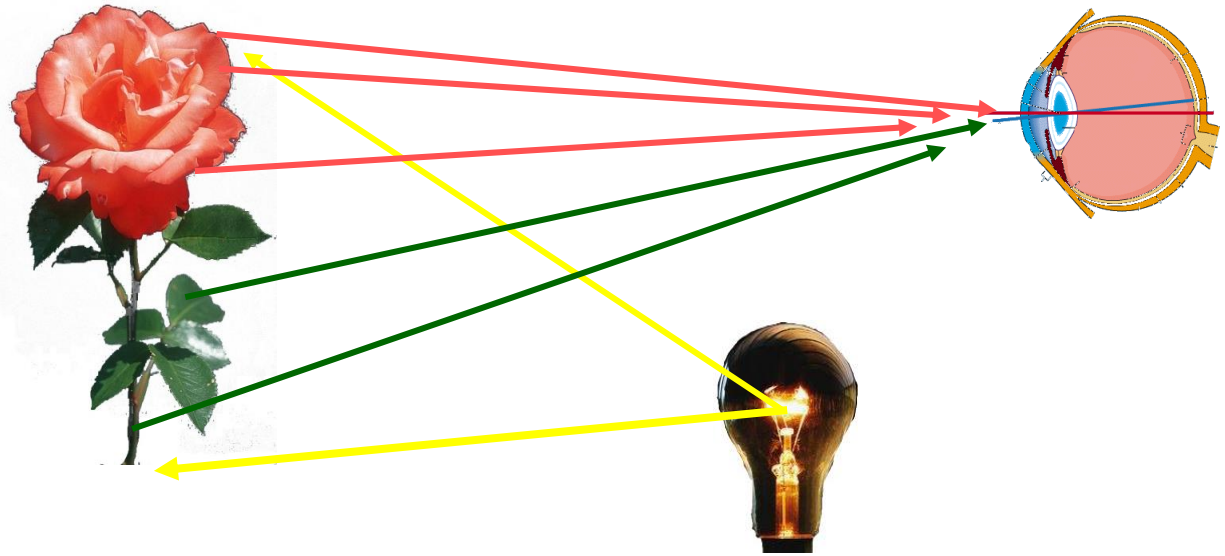
Chemical change versus Physical change

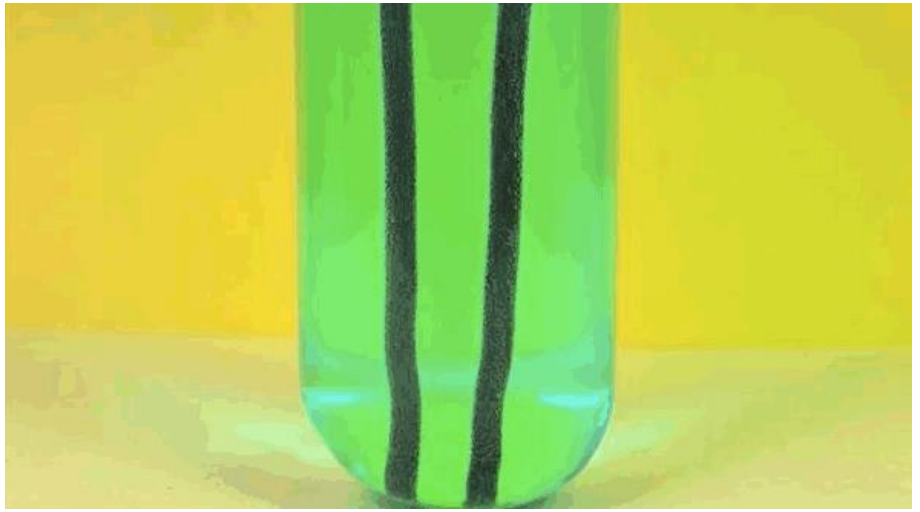
Evidence of Chemical Changes

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



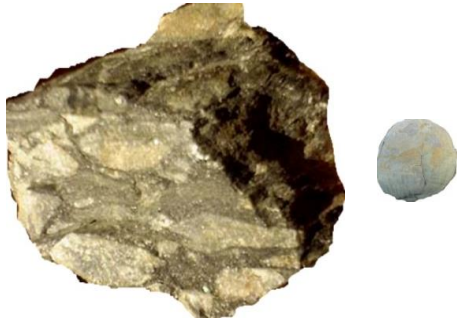


Light hits flower, "bounces off."
Detect (observe) with eye, camera, etc.

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

Big and Small: Relative Concept

Rocks come in all sizes.

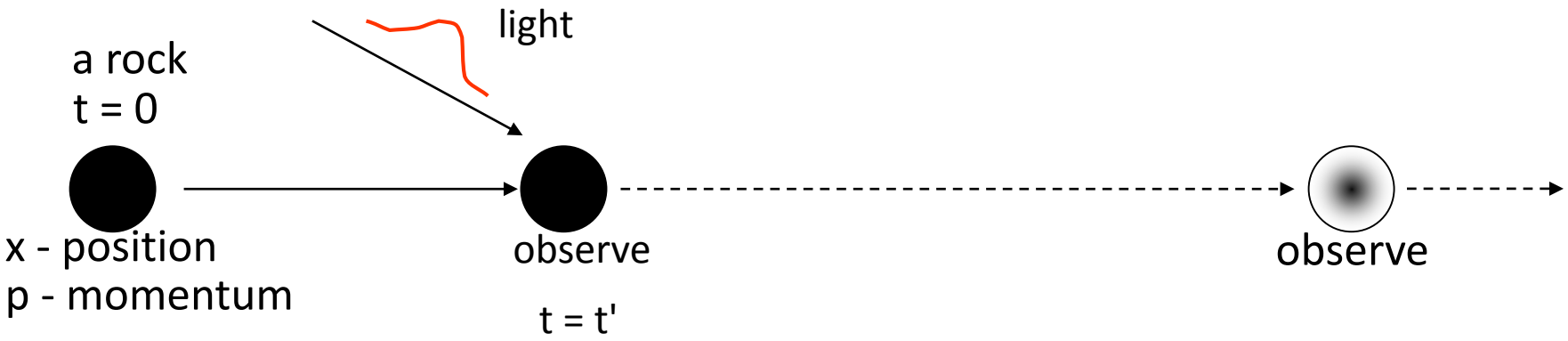


Wrong experiment → wrong size

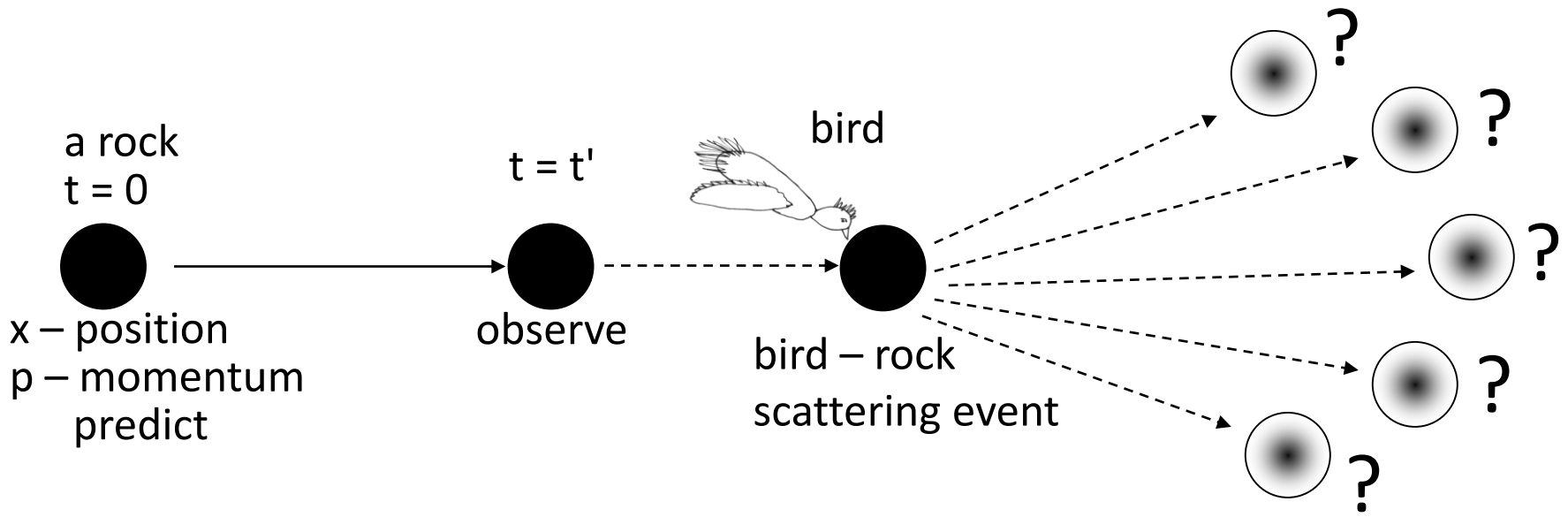
Right experiment → right size

Comparison determines if a rock is big or small.

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

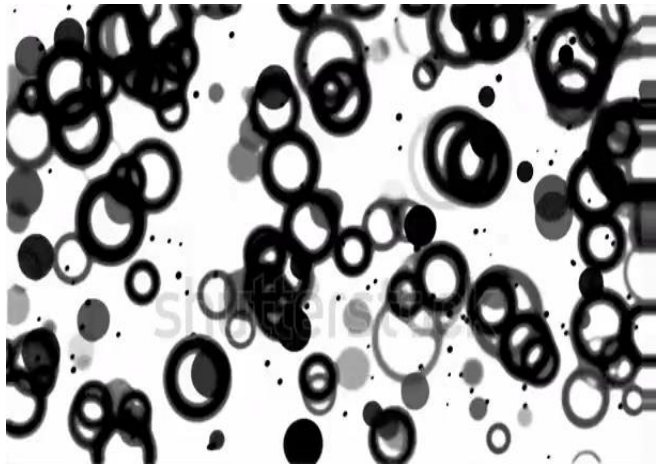


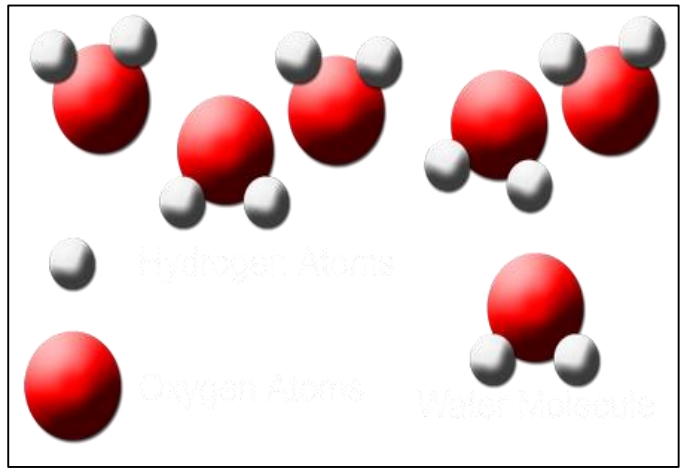
Make observation of trajectory. Predict future location.



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

How small is small?

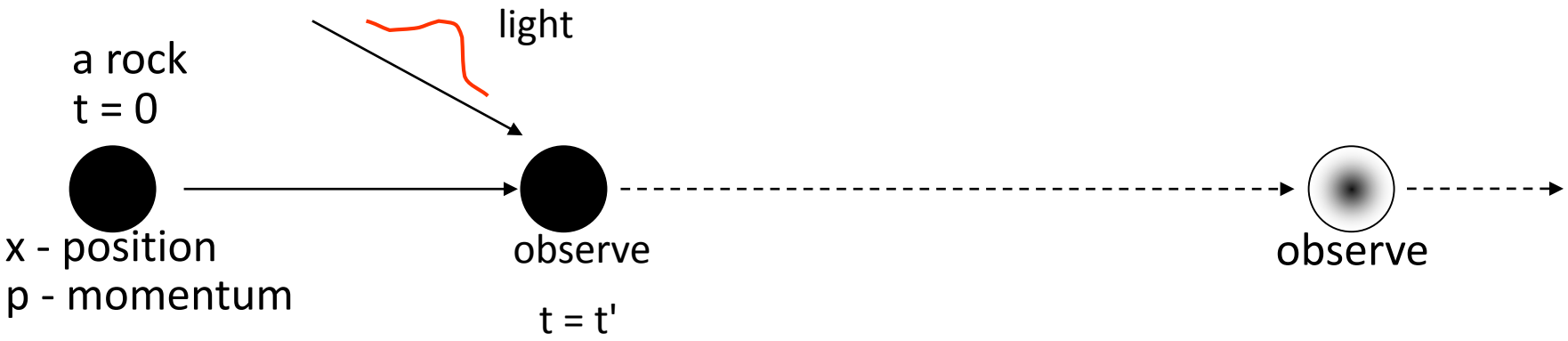




Disturbance caused by observation (measurement)

negligible → object big

non-negligible → object small



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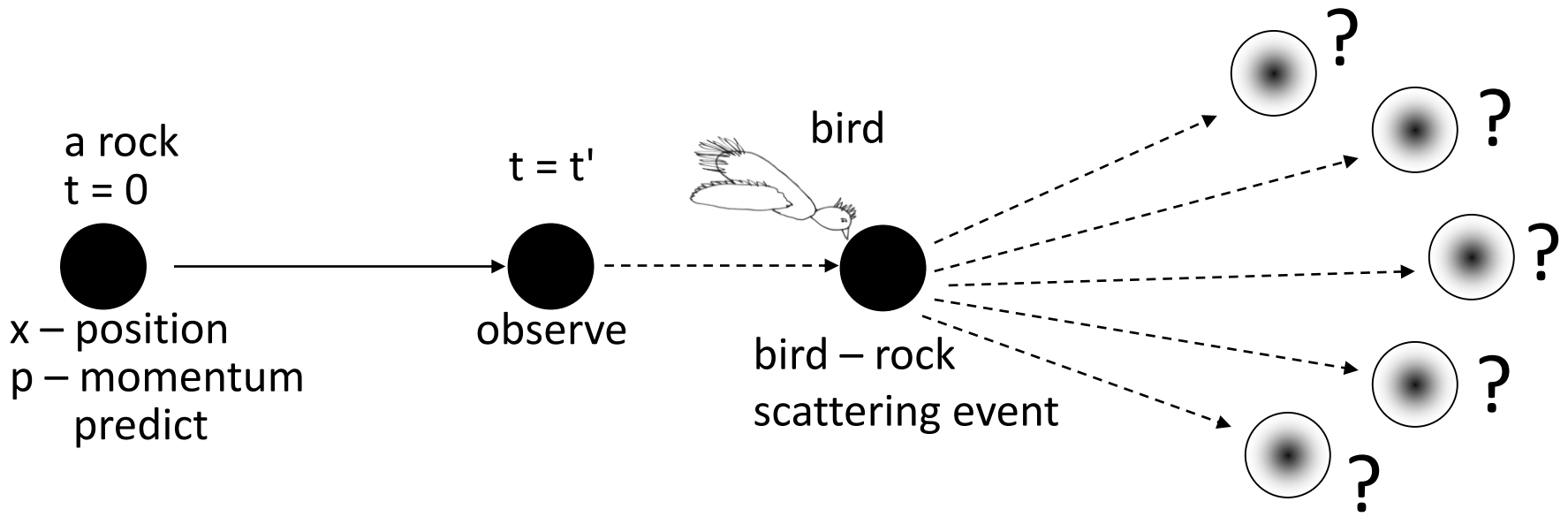
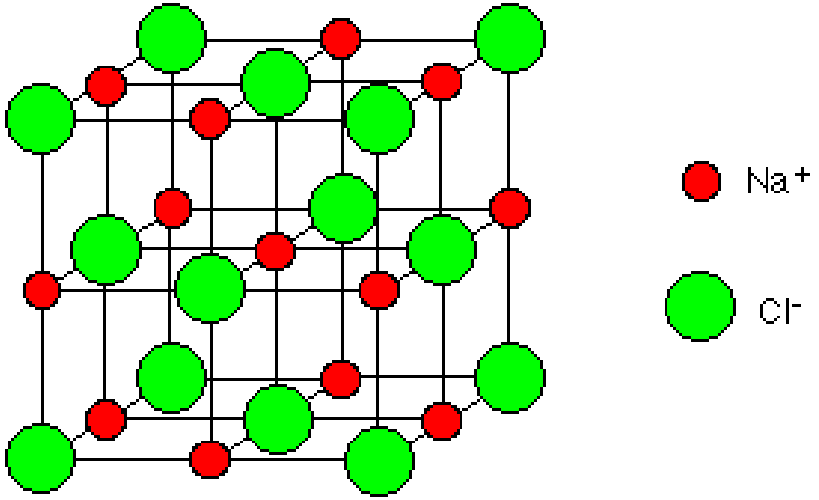
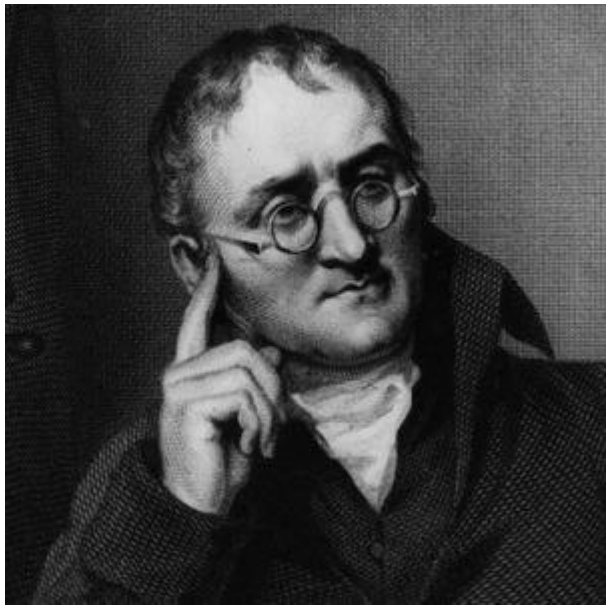


Following non-negligible disturbance – don't know outcome.

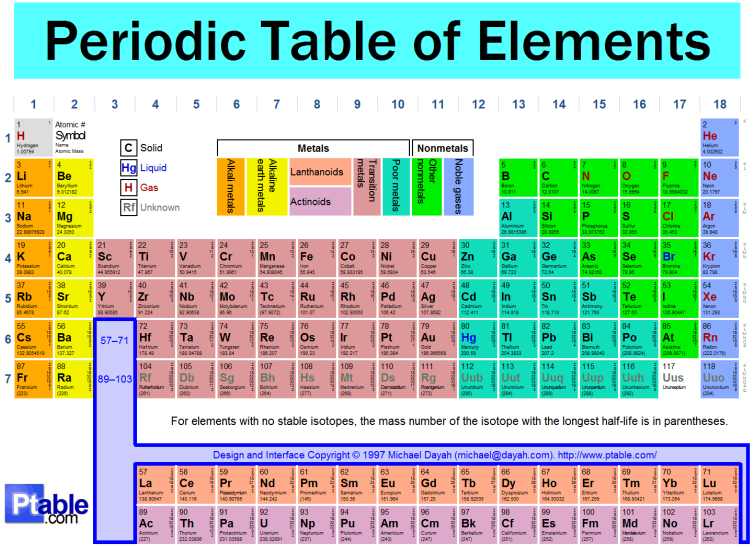
Big Objects (matter) consists of smaller objects

Smaller objects consists of even smaller particles





John Dalton (1776 – 1844)



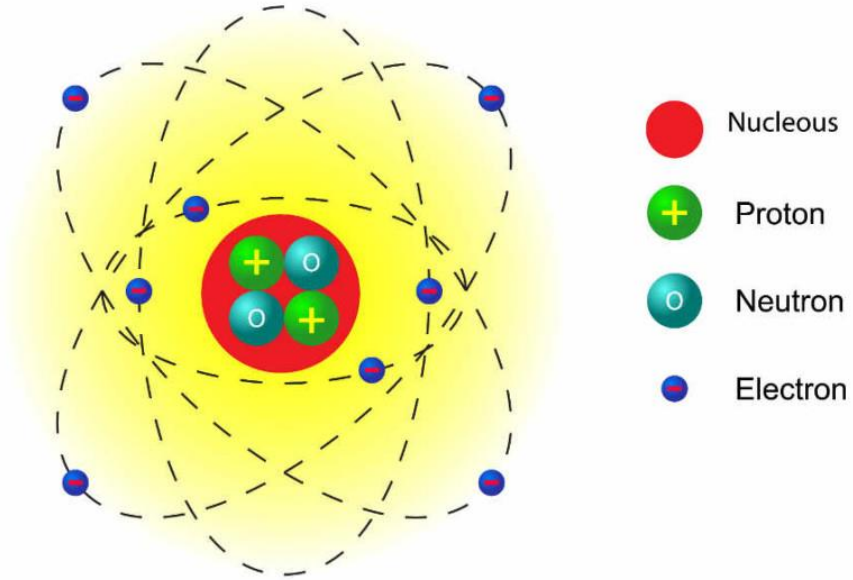
Dalton's Atomic Theory

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.

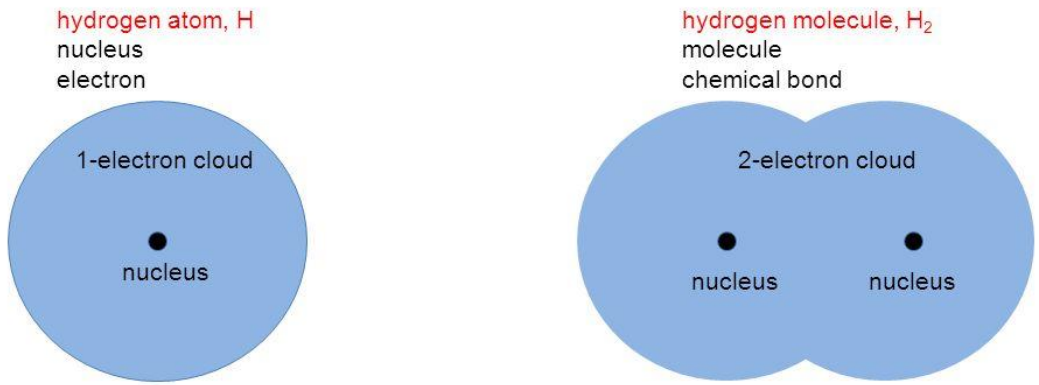
Matter consists of molecules

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

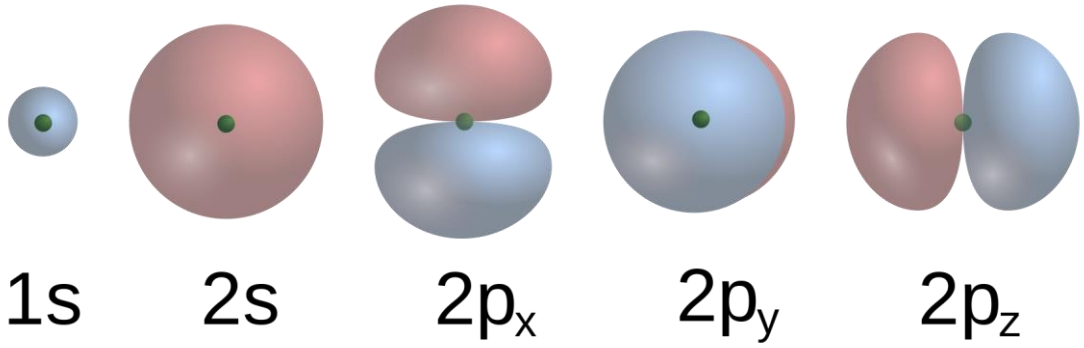
Werner Heisenberg

"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



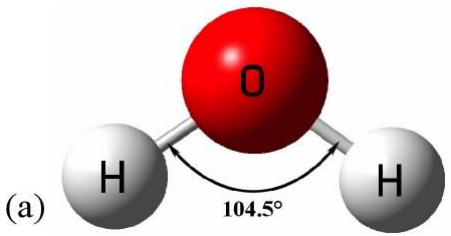
Chemical reaction:

Electrons (orbitals) are meeting first

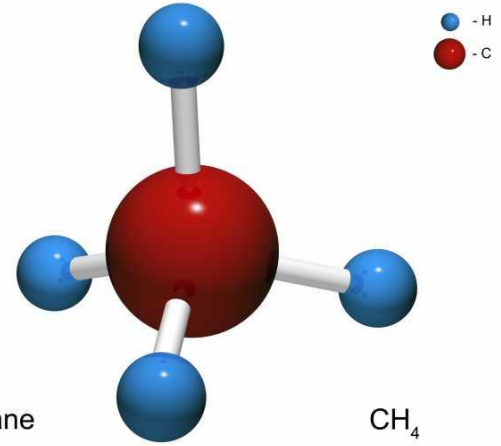
Orbitals have directional property

Reaction will happen in a direction

Compounds form will have a unique structure

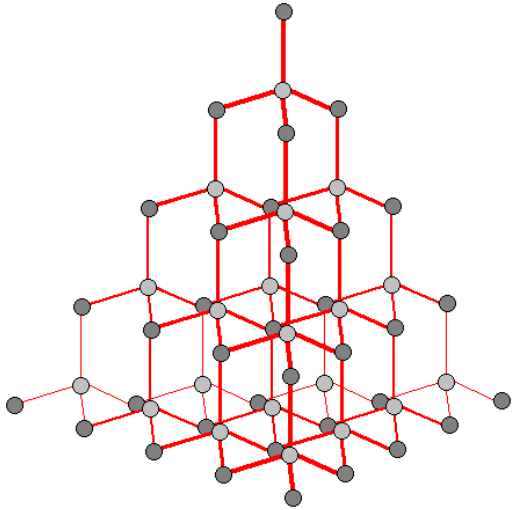


Carbon dioxide

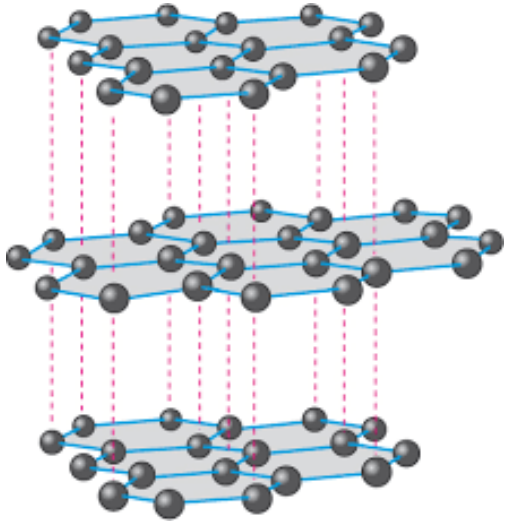


Methane CH_4

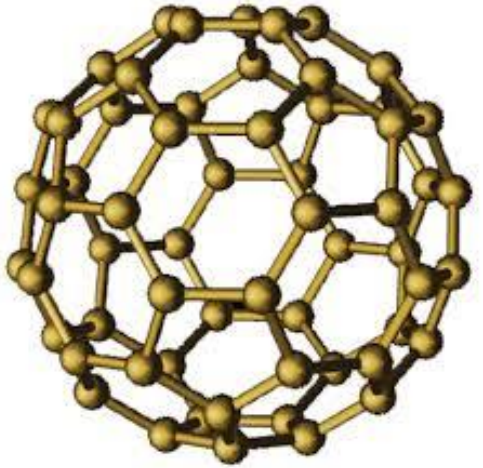
Carbon compounds



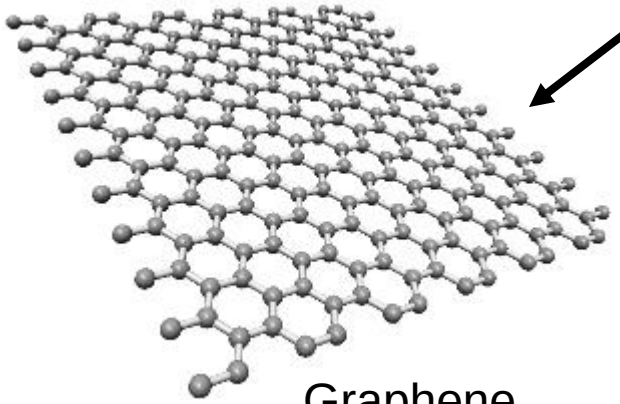
Diamond



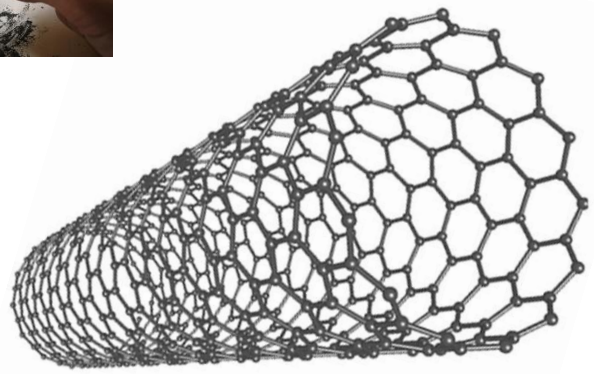
Graphite



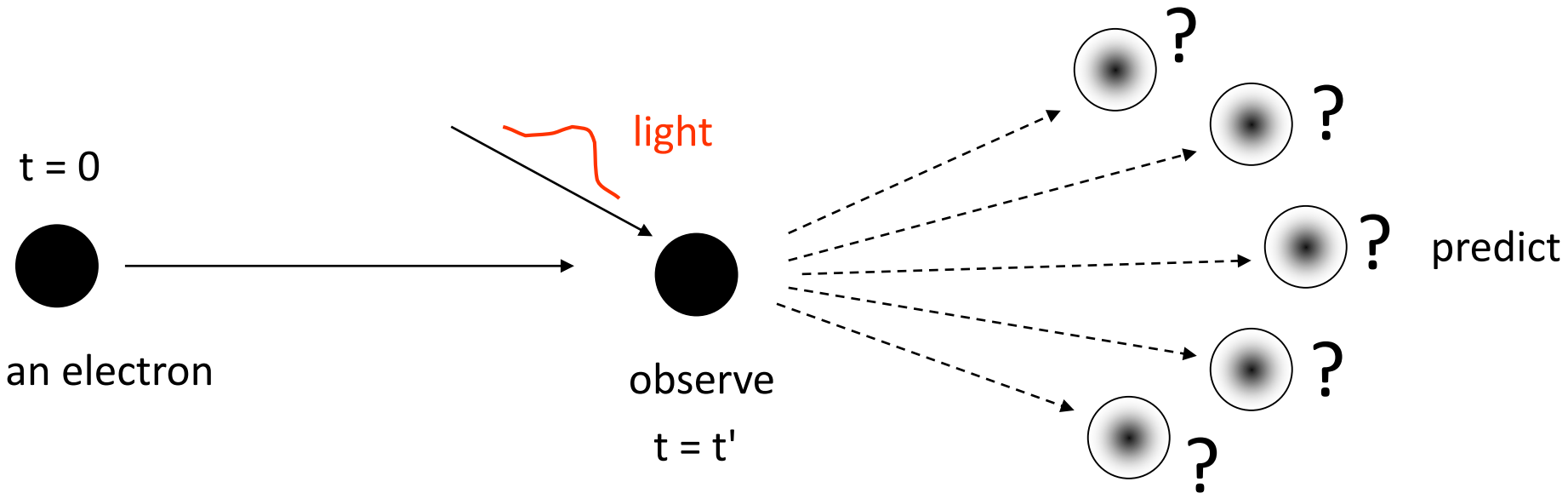
Fullerene



Graphene

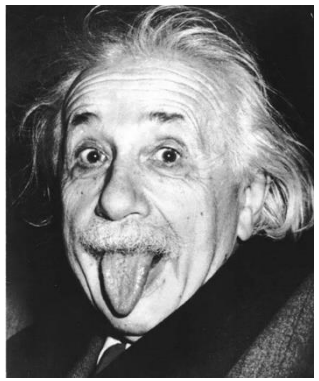


Carbon nanotube



Photon – Electron scattering. Non-negligible disturbance.

Can't predict trajectory after observation.



Albert Einstein
(1879-1955)

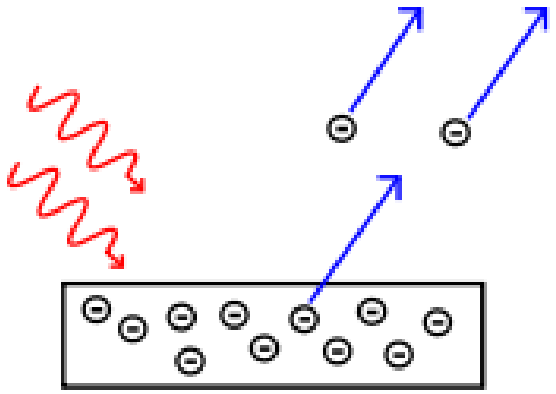
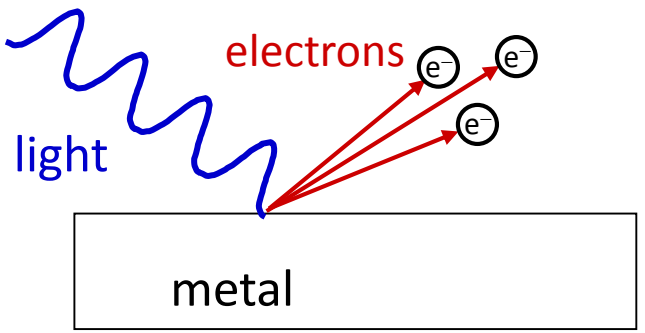


Photo-electric effect

Can we divide light into smaller particles?

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



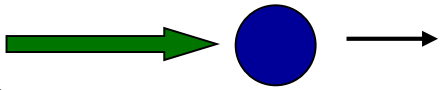
Experimental results

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

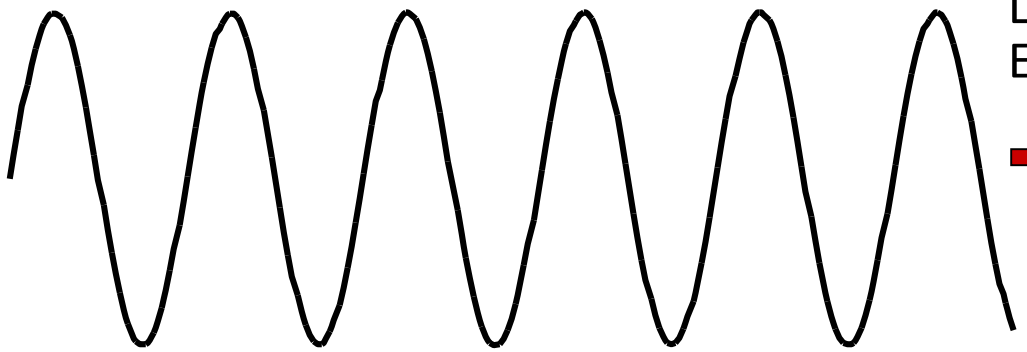
Increase light intensity
get more electrons out with identical speed.

Low Intensity - Small Wave

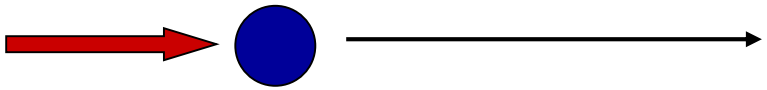
Light wave "hits" electron gently.
Electrons come out – low speed.



High Intensity - Big Wave



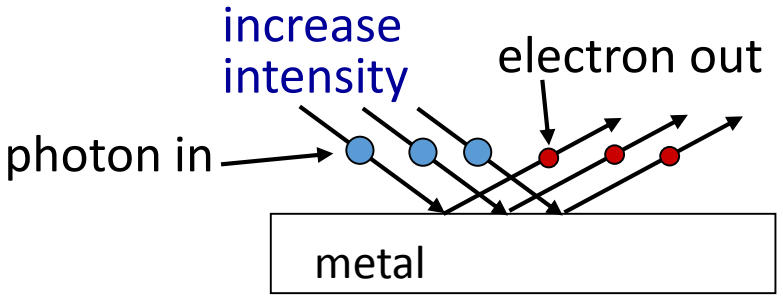
Light wave "hits" electron hard.
Electrons come out – high speed.



Can we divide light into smaller particles?

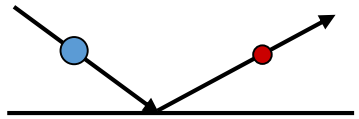
Light is composed of small particles

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.

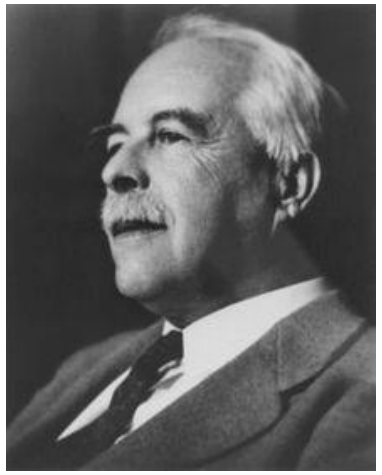
There was a huge debate. No experiment could prove it!

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 ($H+H=H_2$)
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

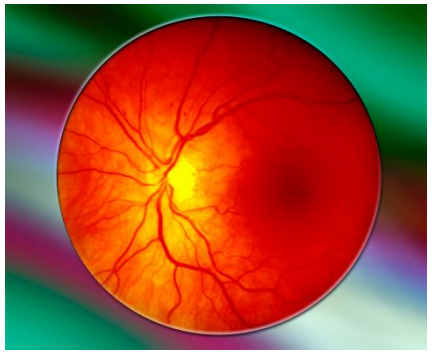
molecule 1 + molecule 2 = light

light 1+ light 2 = light 3

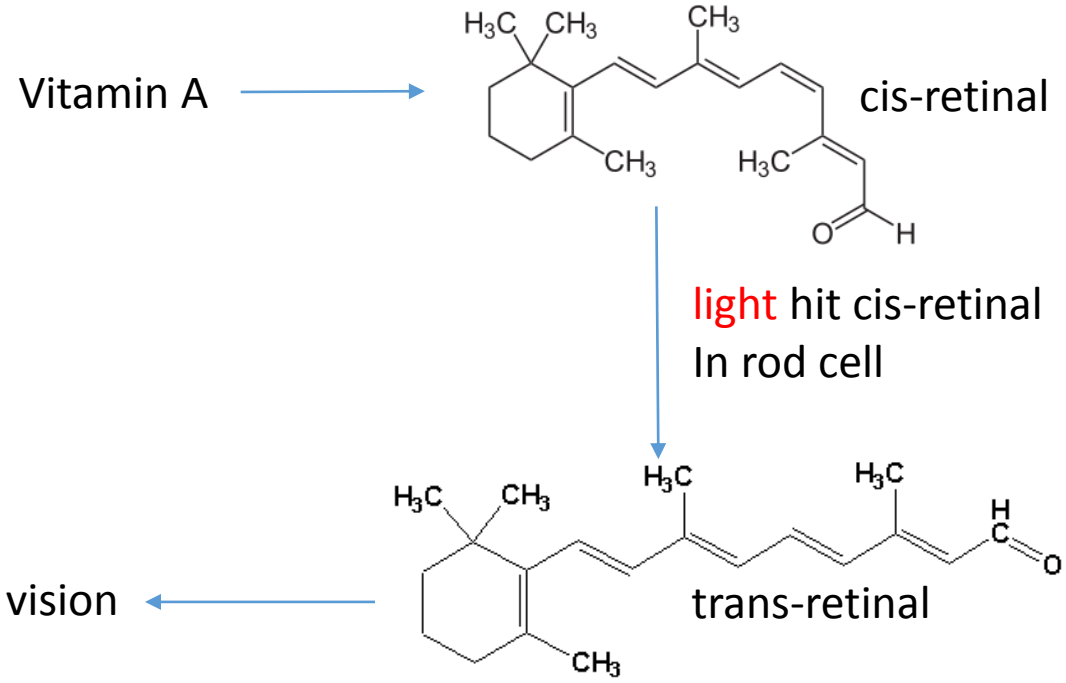
light + molecule 1 = molecule 2

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

Chemistry of Vision

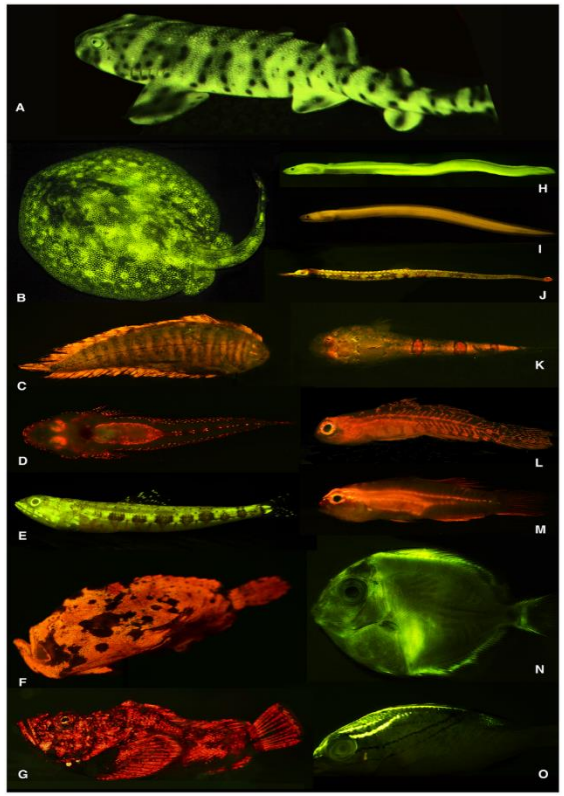


Retina: has rod and cone cells



molecule 1 +light 1 = molecule 2 + light 2

Fluorescence



Marine Fish

Fluorescence in faster than phosphorescence

Phosphorescence

Jelly Fish

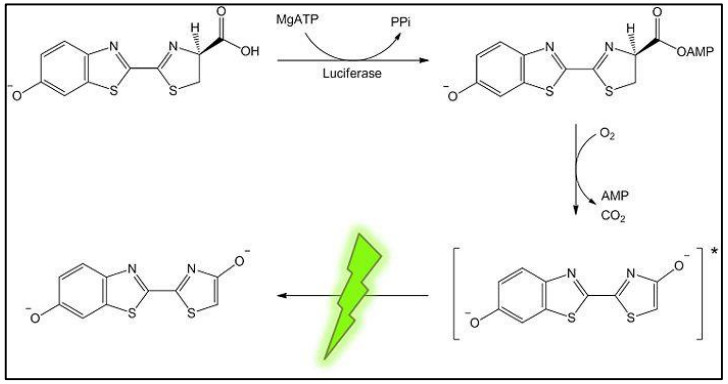
molecule 1 + molecule 2 = light 2

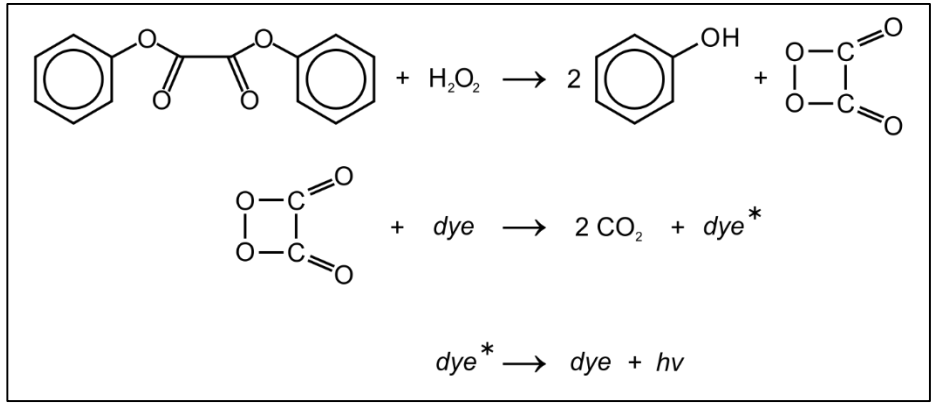
Chemiluminiscence

Emission of light as a result of a chemical reaction

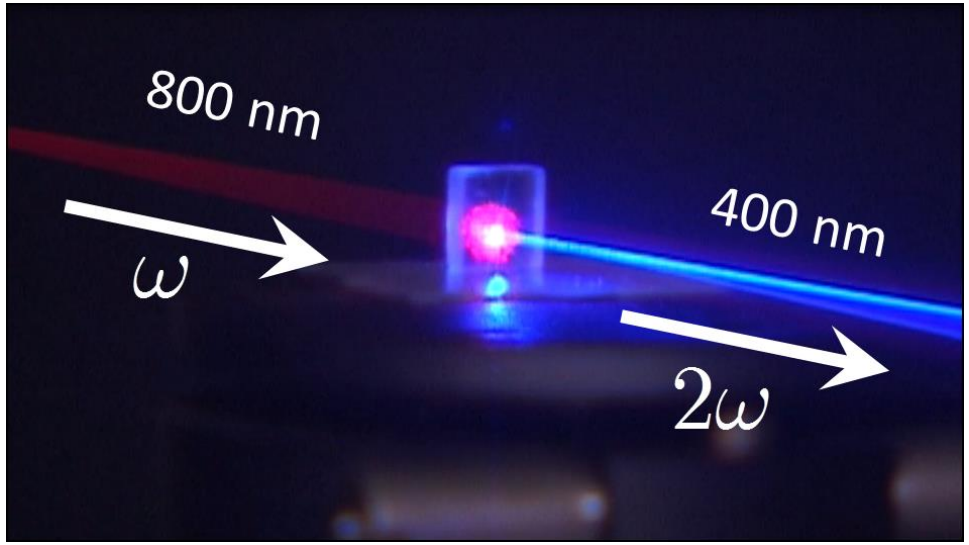
Firefly

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