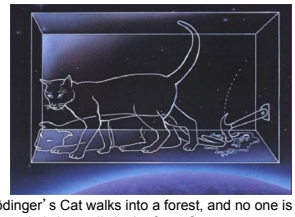
How does light interact with matter?
And what does (this say about) matter?



If Schrödinger's Cat walks into a forest, and no one is around to observe it, is he really in the forest?

- source unknown

Phys 1010 Day 27

Questions? On the nature of models

Farmer/seeds

Light interacting with atoms

Reminders:

Next:spectra, applications like "lasers"

HW will change

FCQs

1

REGISTER!!!

Last Name	First Name
Gurel	Charlotte
Flaherty	Daniel
Sweet	Samuel
Marzano	Stefano
Thammavongsa	William

2

Class Updates

- Scores will be updated by end of week
- Lasers this week
- Review next week
- Final & grades…
- HW for next week – review
  - A) I want both due at same time Monday
  - B) make the HW (short due Monday); Review on Wed?

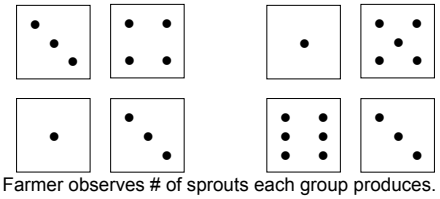
3

The Farmer and the Seeds

(a parable of scientific reasoning)

- A seed is a square with some dots on it.
- The farmer always plants 4 seeds in a group.

First Group: Second Group:

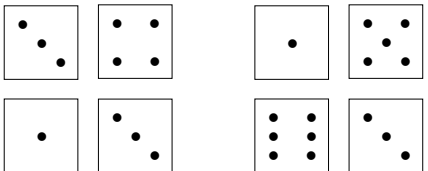


- Farmer observes # of sprouts each group produces.

4

The Farmer and the Seeds

First Group: Second Group:



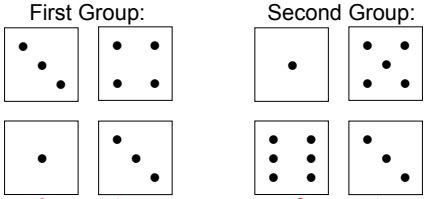
4 sprouts **6 sprouts**

- ***What do you think?***
  What schemes can we come up with that would predict the number of sprouts ***based on the dot pattern showing*** when the seeds are planted?

5

The Farmer and the Seeds

First Group: Second Group:



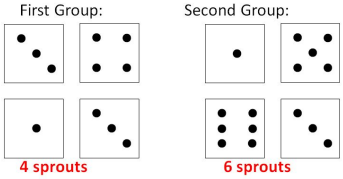
4 sprouts **6 sprouts**

- ***What does your group think?***
  When everyone has come up with at least one scheme, share your schemes with your group

6

The Farmer and the Seeds

First Group: Second Group:



4 sprouts 6 sprouts

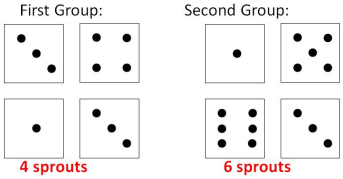
Possible Schemes

1. Totally Random (Numbers aren't related to # of sprouts)
2. (Largest Number) = (# of Sprouts)
3. . . .
4. . . .

12

The Farmer and the Seeds

First Group: Second Group:



4 sprouts 6 sprouts

Possible Schemes

1. Totally Random (Numbers aren't related to # of sprouts)
2. (Largest Number) = (# of Sprouts)
3. (Number that is even) = (# of Sprouts)
4. (Second Largest Number) + (Smallest Number) = (# of Sprouts)
5. [(Sum of all Numbers) – 3] / 2 = (# of Sprouts)

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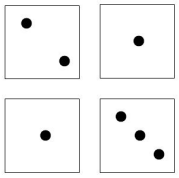
Another seed grouping the farmer

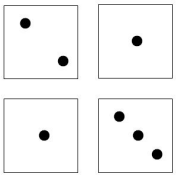


Possible Schemes

1. Totally Random (???)
2. (Largest Number) =
3. (Number that is even) =
4. (Second Largest Number) + (Smallest Number) =
5. [(Sum of all Numbers) – 3] / 2 =

14

Another seed grouping the farmer



2 sprouts!

Possible Schemes

1. Totally Random (???)
2. ~~(Largest Number) = 3 Sprouts~~
3. (Number that is even) = 2 Sprouts
4. ~~(Second Largest Number) + (Smallest Number) = 3 Sprouts~~
5. [(Sum of all Numbers) – 3] / 2 = 2 Sprouts

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Questions from this story:

Possible Schemes

1. Totally Random (???)
2. (Number that is even) = 2 Sprouts
3. [(Sum of all Numbers) – 3] / 2 = 2 Sprouts

1. How could we decide if any of these three schemes is the correct one?
2. If the farmer had to wait to plant more seeds, are there reasons we might in the meantime favor one scheme over another?
3. How do we know if we've figured out all the possible schemes?
4. Where did these schemes we've been discussing come from? (Note: This question is not about the elements of the schemes, but the decisions as to what elements to use and how to use them.)

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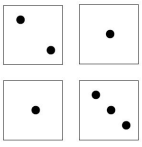
A MODEL

=



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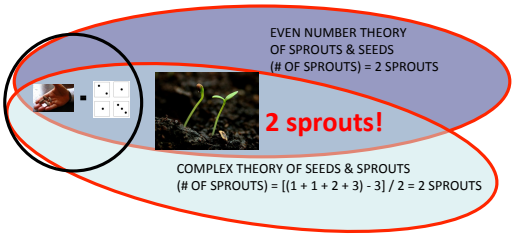
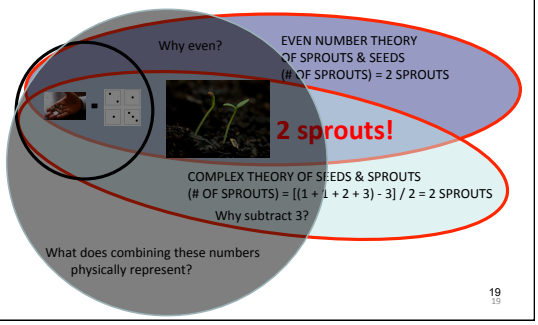
COMPETING THEORIES



…constrained by observation

INTERPRETATION



Summary

- Scientists "make up" theories to explain the evidence they see.
- These theories are constrained by experiment.
- We can't always open up the seed and look inside. Have to make inferences from indirect evidence.
- A theory with a plausible mechanism is more convincing than a rote algorithm.
- The more different cases our theory works on, the more we believe it.
- But it could always be wrong…

Learning Goals

1. How Rutherford scattering established atom made up of small heavy nucleus with large cloud of light electrons.
2. What one sees if bash atoms with anything, particularly electrons, as in a discharge lamp.
3. What light coming from atoms ("spectra") imply about behavior of electrons in atom.

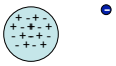
We will combine with understanding of light as a wave and a particle.

We will return to this once we understand the atom better and where light comes from.

Prior models of atom

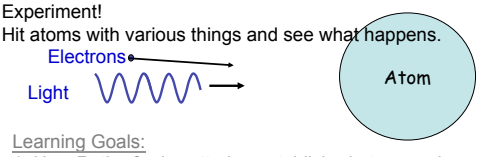
- Atom - Greek indivisible unit

- But wait we can get electrons from them (scraping, or chemical)



Develop model of how light interacts with and is produced by *individual* atoms & what that tells us about how to describe atoms and about behavior of electrons in atoms

How to look at structure of atoms?
Experiment!
Hit atoms with various things and see what happens.



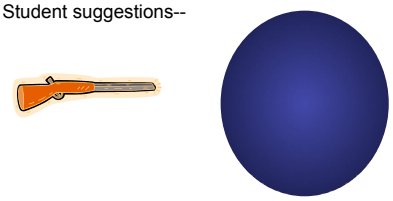
Learning Goals:

1. How Rutherford scattering established atom made up of small heavy nucleus with large cloud of light electrons.
2. What one sees if bash atoms with anything, particularly electrons, as in a discharge lamp.
3. What light coming from atoms ("spectra") imply about behavior of electrons in atom.

Investigating Atoms: An analogy with JELL-O ball

Have a heavy blob that seems like grape JELLO, and you have gun with rubber bullets. How to find out what the middle of the blob is like?

Student suggestions--



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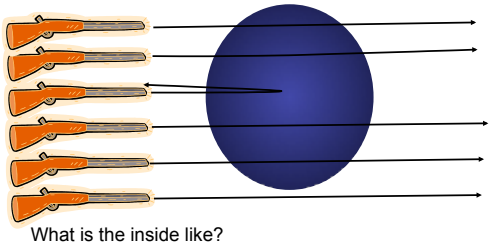
Have a heavy blob that seems like grape JELL-O, and you have gun with rubber bullets. How to find out what the middle of the blob is like? Shoot bunch of bullets into it and see this.



What is the inside like?

a. hollow
b. solid JELLO
c. hard heavy core surrounded by JELLO
d. bunch of hard little objects distributed through blob

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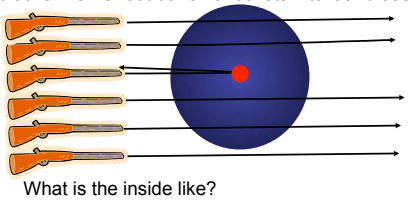
Have a heavy blob that seems like grape jello, and you have gun with rubber bullets. How to find out what the middle of the blob is like? Shoot bunch of bullets into it and see this.



What is the inside like?

c. hard heavy core surrounded by JELLO

Object must be hard and heavy to reflect.

Essentially Rutherford experiment and conclusion.

Rutherford shot alpha particles = 2 protons, 2 neutrons

Bullets = Positive charge

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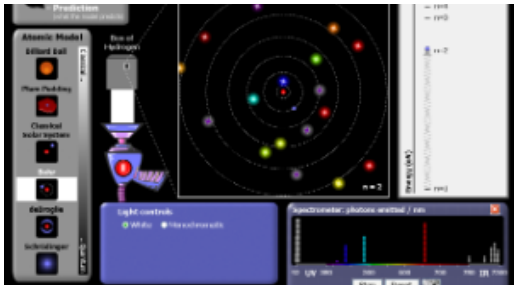
Atom Sim



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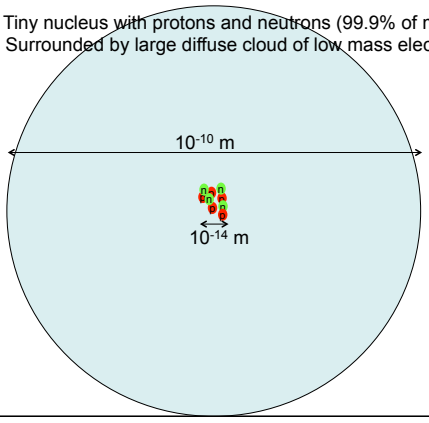
Atom: Tiny nucleus with protons and neutrons (99.9% of mass)
Surrounded by large diffuse cloud of low mass electrons



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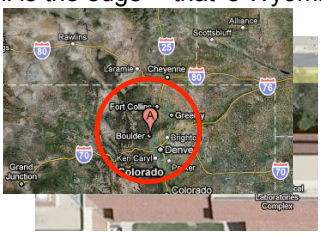
Google map perspective

- 50' is the nucleus (that's Gamow Tower)
- 100mi is the edge -- that's Wyoming!



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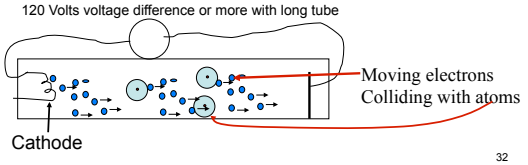
Item 2: Bash atoms with electrons and see what happens

Look at with diffraction gratings and atomic discharge lamps. Mercury, Sodium, neon

Hold grating only by edges...oil from hands ruins grating.
Hold close to eye... See rainbow from lights.
Turn so rainbow is horizontal.

In atomic discharge lamps, lots of electrons given bunch of energy (voltage). Bash into atoms. *("Neon" lights, Mercury street lamps)*



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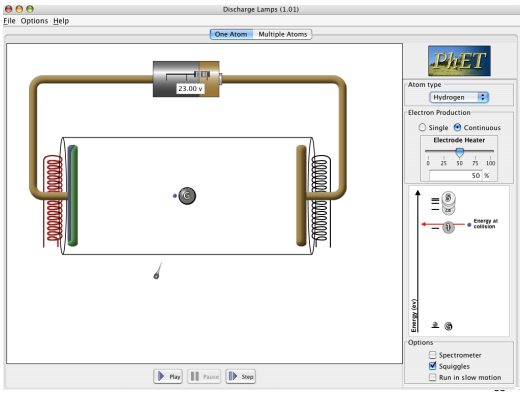
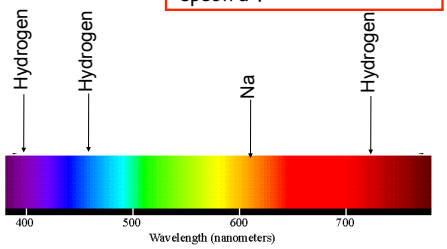


What colors from white light?
What colors from hydrogen?
What from sodium?
What from mercury?
What colors from neon?

White light = whole spectrum
Each type of atom produces unique set of colors.
Called its "spectrum", plural "spectra".



Each type of atom produces unique set of colors.

Discussion: if we know that different colors of light represent different energies, what does this mean about atoms?

Student suggestions:
a.
b.
c.
d.
e.

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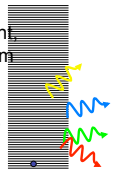
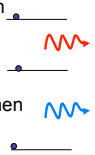
Review of atom discharge lamps-- neon signs.

Energy levels metal, bulb filament, or not stuck in atom (like sun). If hot, jump between all diff. levels. Wiggle around, all colors.

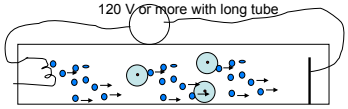


Energy levels in isolated atom.

kick up, only certain wavelengths when come down.



In discharge lamps, lots of electrons given bunch of energy (voltage). Bash into atoms. *("discharge tube")*



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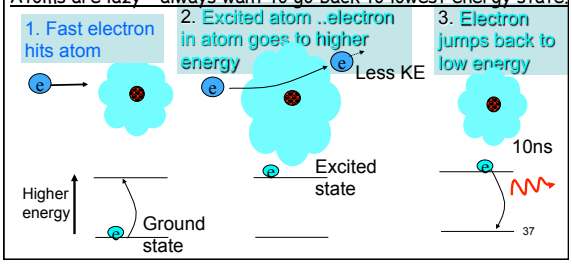
Discussion: Given what we know about light, what does this imply about electrons in atoms?
Implies that electrons only change between very specific energies.
Only way for *individual* atoms to give off energy is as light.
Each time a photon is emitted an electron must be changing in energy by that amount (*releasing* energy). (basics, applications)

Atoms are lazy - always want to go back to lowest energy state.



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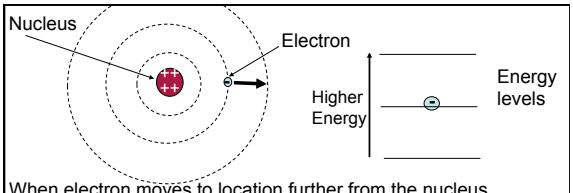

When electron moves to location further from the nucleus,

a. energy of electron *decreases* because energy is released as positive and negative charges are separated, and there is a *decrease* in electrostatic potential energy of electron since it is now further away

b. energy of electron *increases* because it takes energy input to separate positive and negative charges, and there is an *increase* in the electrostatic potential energy of the electron.

c. energy of electron *increases* because it takes energy input to separate positive and negative charges, and there is a *decrease* in the electrostatic potential energy of the electron.

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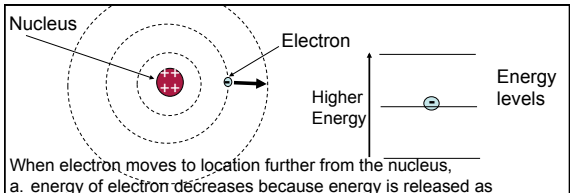

When electron moves to location further from the nucleus,

a. energy of electron decreases because energy is released as positive and negative charges are separated, and there is a decrease in electrostatic potential energy of electron since it is now further away

b. energy of electron increases because it takes energy input to separate positive and negative charges, and there is an increase in the electrostatic potential energy of the electron.

c. energy of electron increases because it takes energy input to separate positive and negative charges, and there is a decrease in the electrostatic potential energy of the electron.

(*Force* on electron is less, but *Potential Energy* is higher!)

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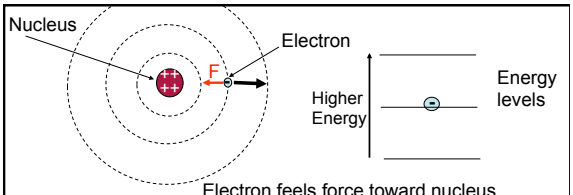

Electron feels force toward nucleus.
Must work against that force to move electron farther away, so increase in PE.

When electron moves to location further from the nucleus,
Answer is b. energy of electron increases because it takes energy input to separate positive and negative charges, and there is an increase in the electrostatic potential energy of the electron. It's like pushing a boulder out of a ditch (steep at first and shallow later on).

So electrons at higher energy levels are further from the nucleus!

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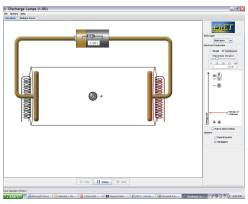

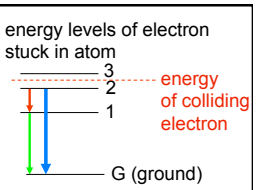

If the colliding electrons have an energy between that of level and level 3 when they hit the atom

a. no levels will be excited, and so no light will come out.
b. 1 color of light will come out
c. 2 colors of light will come out
d. 3 colors of light will come out
e. 4 colors come out.

ans. d. enough energy to excite level 2, then get **2⇒1** followed by **1⇒G**, but also can go **2⇒G**.

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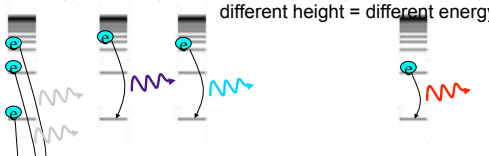
Energy level diagrams- represent energy electron can go to.
different height = different energy

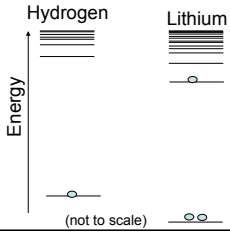


For Hydrogen, transitions to ground state in ultraviolet!

No light emitted with colors in this region because no energy levels spaced with this energy.

<u>Important Ideas</u>

1) Electrons in atoms only found in specific energy levels
2) Different set of energy levels for different atoms
3) 1 photon emitted per electron jump <u>*down*</u> between energy levels. Photon color determined by energy difference.
4) electron spends very little time (10^{-8} s) in excited state before hopping back down to lowest unfilled level.
5) If electron not stuck in atom, can have any energy.



Electron energy levels in 2 different atoms …
Levels have different spacing.

Atoms with more than one electron … lower levels filled.

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