LECTURE 10
CHAPTER 14

PHY 100. BOHR, SCHRODINGER

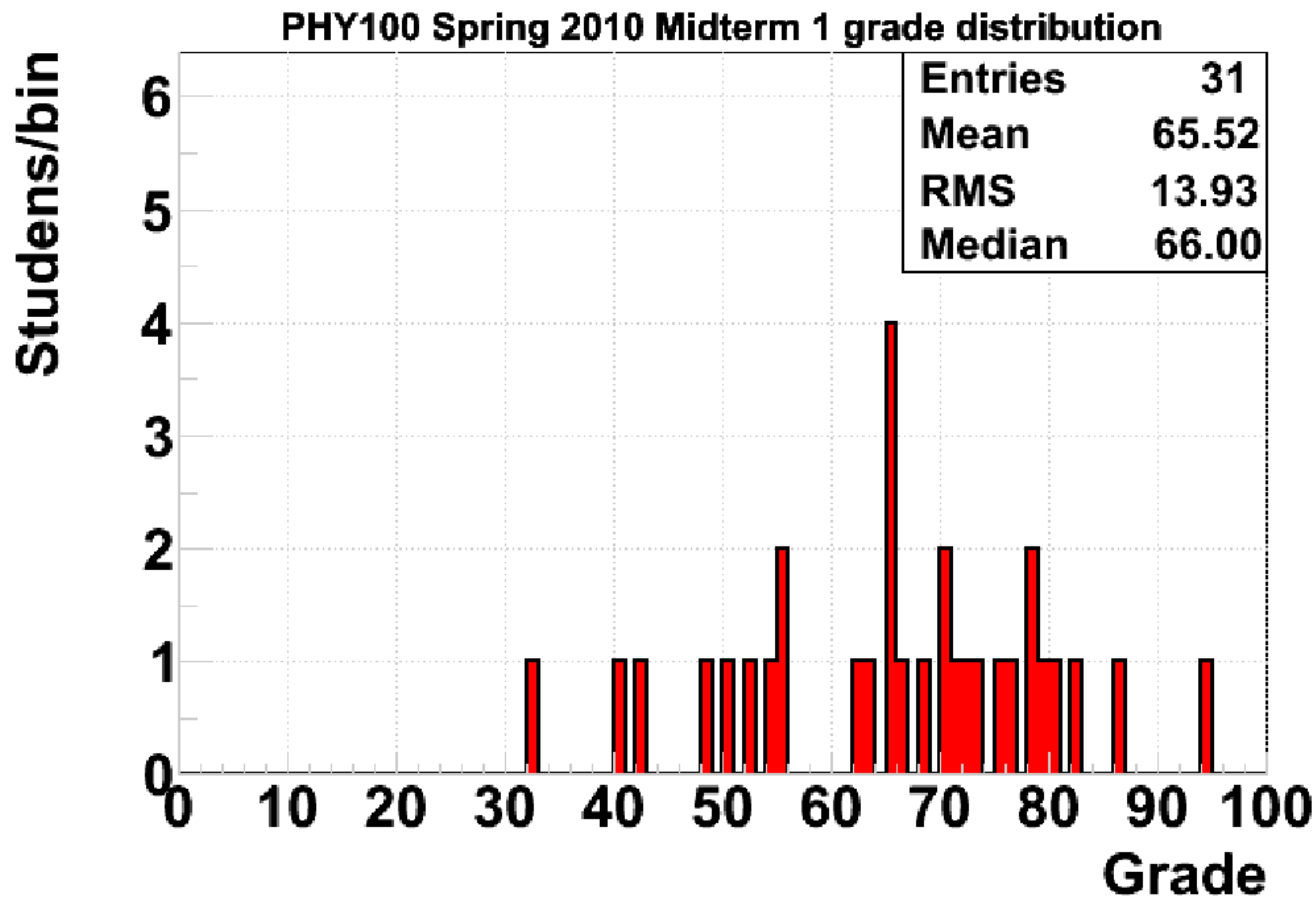
- RETURN CHOICES FOR PRESENTATION TOPIC BY WEDNESDAY.
- FILL IN TA SURVEY
- MIDTERM 1 GRADED

→ OVERALL GOOD JOB

NEED TO MAKE SURE YOU PRACTICE SOME PROBLEMS

GET COMFORTABLE WITH SOME BASIC MATH LIKE COMPARING TWO EQNS.

THINK BEFORE YOU BLINDLY PLUG IN NUMBERS



1. Is it possible to prove, for certain, that a scientific theory is false?

(a) Yes, by means of a single confirmed experiment that contradicts the theory

(b) Yes, by taking a vote among all scientists who are experts concerning the theory

(c) Yes, by performing a large number of experiments and finding that the outcomes that dispute the theory outnumber the outcomes that support the theory

(d) No, because it is always possible that future experiments will agree with the theory

(e) No, because science can never be certain of anything

TIME DILATION : $T = \gamma T'$

PROPER TIME: MEASURED ON SYSTEM THAT IS MOVING, AT REST ON ITS REF. FRAME.

LENGTH CONTRACTION : $L' = \gamma L$

PROPER LENGTH

$m \sim \gamma m'$ → THAT'S WHY YOU CANNOT REACH C IF YOU AKE A MASSIVE OBJECT, BECAUSE YOUR MASS APPEARS AS ∞ TO AN OUTSIDE OBSERVER

$$\gamma = \frac{1}{\sqrt{1 - \left(\frac{v}{c}\right)^2}}$$

$$F_E = \frac{G M_E m}{R_E^2} \qquad \frac{G M_E}{R_E^2} = g_E$$

$$F_J = \frac{G M_J m}{R_J^2} \qquad \frac{G M_J}{R_J^2} = g_J$$

$M_J = 300 M_E$

$R_J = 10 R_E$

QUESTION:

g_J IN TERMS OF g_E ?

① $$g_J = \frac{G M_J}{R_J^2} = \frac{G\, 300 M_E}{(10 R_E)^2} = \frac{300}{100} \times \frac{G M_E}{R_E^2} = 3 \frac{G M_E}{R_E^2} = 3 g_E$$

② $$\frac{g_J}{g_E} = \frac{\cancel{G} \frac{M_J}{R_J^2}}{\cancel{G} \frac{M_E}{R_E^2}} = \frac{M_J}{M_E} \times \frac{R_E^2}{R_J^2} = 300 \times \left(\frac{1}{10}\right)^2 = \frac{300}{100} = 3$$

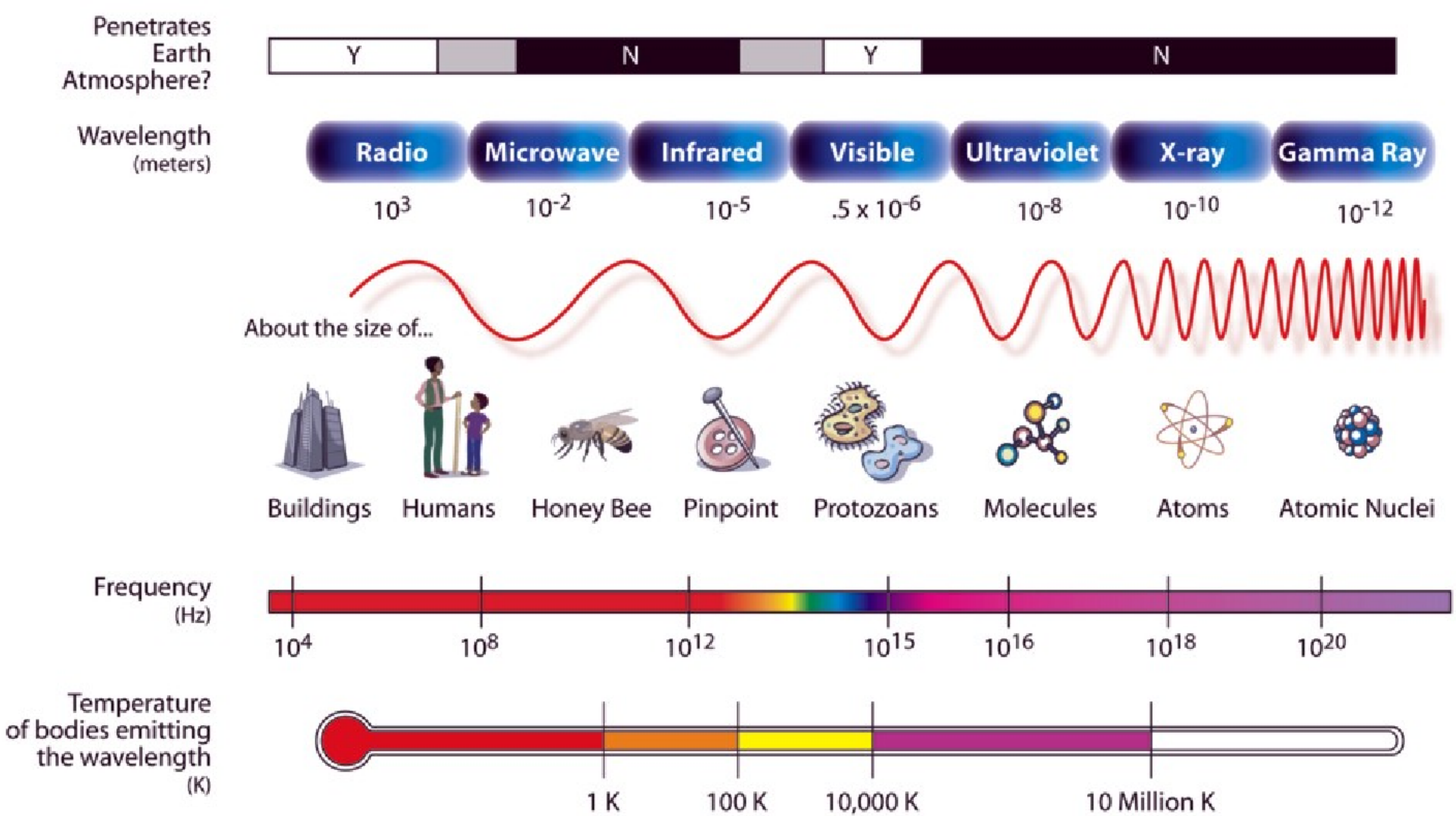
$$\frac{M_J}{M_E} = 300$$

$$\frac{R_E}{R_J} = \frac{1}{10}$$

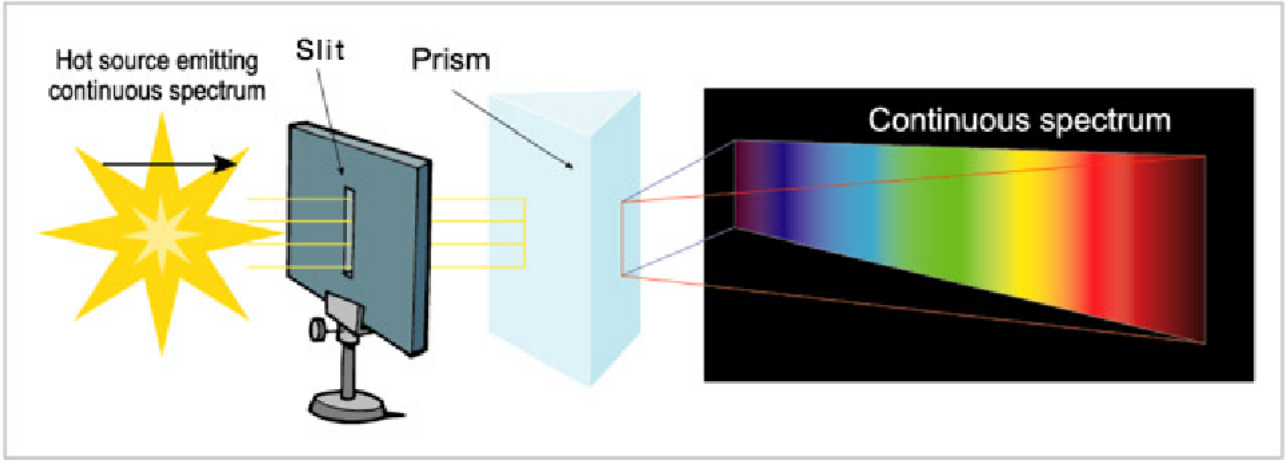
VISIBLE LIGHT IS ONLY A TINY FRACTION OF THE TOTAL SPECTRUM.

VISIBLE LIGHT IS THE COMBINATION OF MANY COLORS (FREQ)

THE ELECTROMAGNETIC SPECTRUM

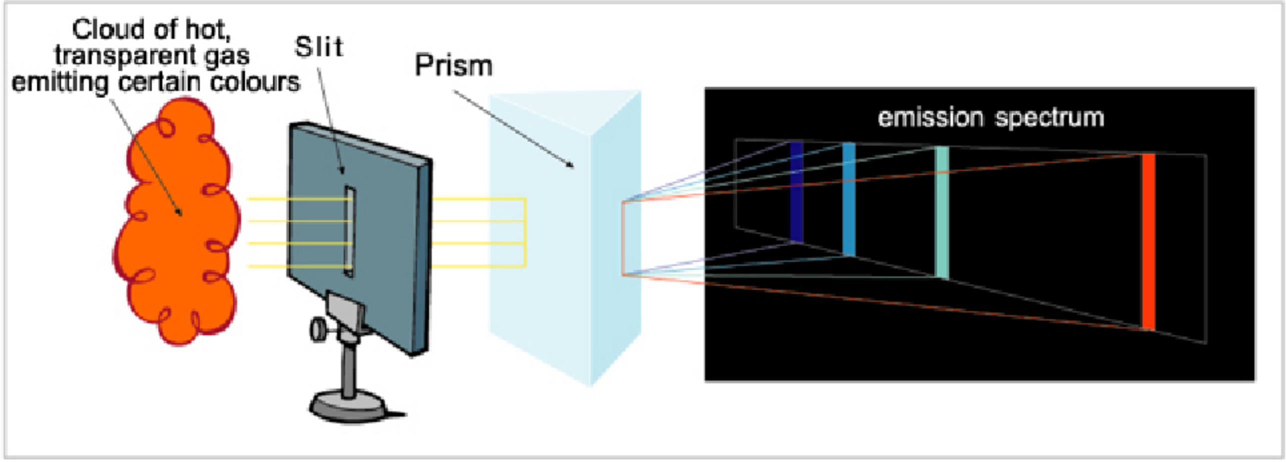


LIGHT FROM MANY ATOMS

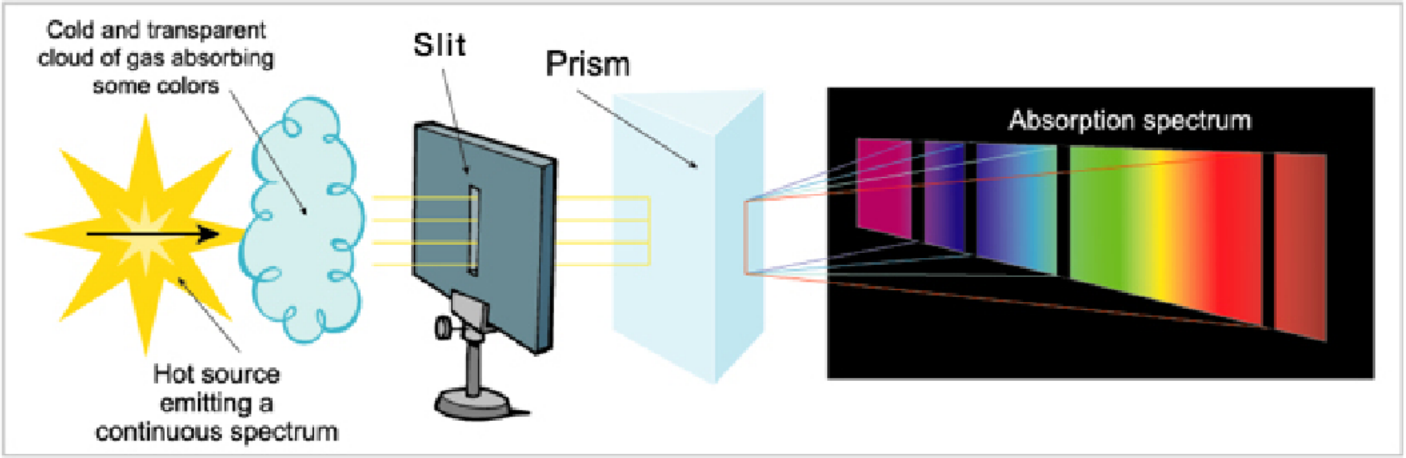


CONTINUOUS f

LIGHT FROM SPECIFIC ATOMS



DISCRETE f (EMISSION)



(ABSORPTION SPECTRUM)

DIFFERENT ATOMS

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DIFFERENT DISCRETE f PATTERN

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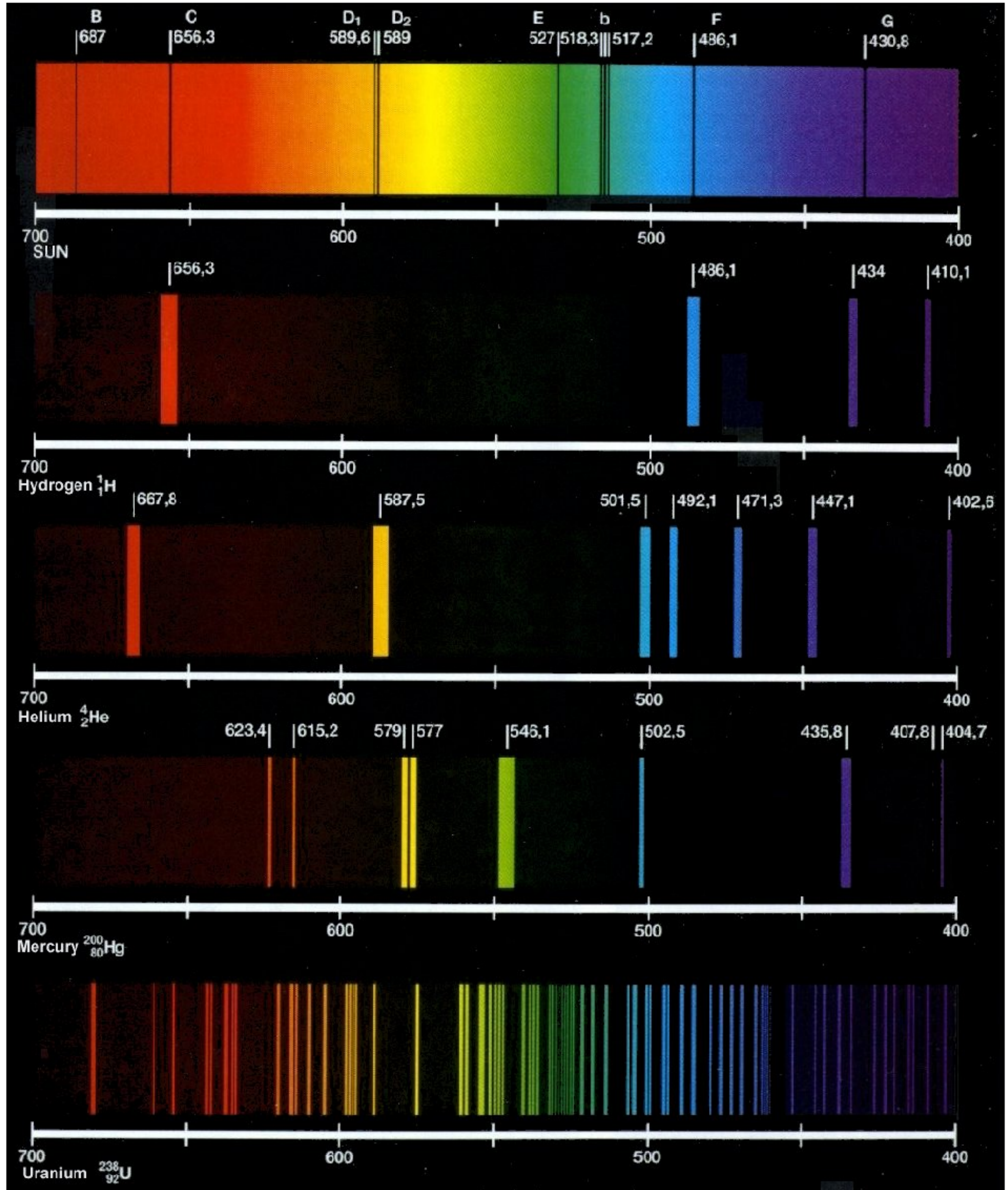
ATOMIC FINGERPRINTING



SUN

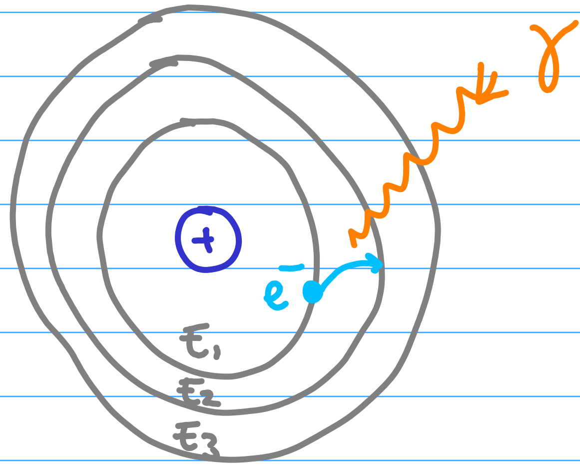
H

He

Hg

U

BOHR'S MODEL OF THE ATOM



PHOTON

$E = hf$

- CIRCULAR ORBITS
- ELECTRIC ATTRACTION KEEPS ATOM STABLE
- DISCRETE ORBITS
  - → DISCRETE RADII
  - → DISCRETE ENERGIES

PHOTONS EMITTED OR ABSORBED BY e^- MAKING TRANSITIONS BETWEEN ORBITS

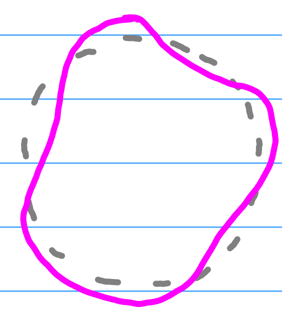
ENERGY DIFFERENCE BETWEEN ORBITS = ENERGY OF PHOTON

THIS PICTURE IS NOT QUITE RIGHT

WE SHOULD THINK OF DE BROGLIE MATTER WAVE $\left(\lambda = \frac{h}{p}\right)$ INTERFERING WITH ITSELF

↓

DISCRETE ORBITS



SCHRÖDINGER EQUATION

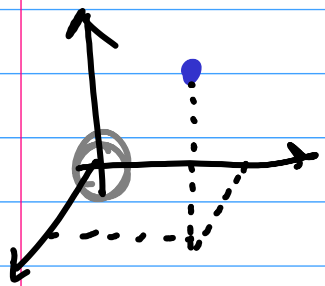
$$-\frac{\hbar^2}{2m}\frac{\partial^2\psi(x)}{\partial x^2} + V\psi(x) = E\psi(x)$$

AS IMPORTANT TO Q.M. AS NEWTON'S LAWS TO CLASSICAL MECHANICS

THIS EQN. DESCRIBES THE PROPER WAVE EQ. FOR THE ELECTRON

BUT IT IS A GENERAL FORMULATION FOR ALL MATTER WAVES

PRESCRIPTION: 1) PUT e^- IN SPHERICAL SYMMETRY



2) PUT e^- IN SCHRÖDINGER EQN. AND SOLVE IT

RESULT: PARTICULAR ALLOWED SPATIAL STATES FOR e^-

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PARTICULAR ENERGIES ALLOWED

SOLUTIONS OF SCHRÖDINGER EQUATION FOR HYDROGEN

DIFFERENT QUANTUM STATES WHERE e^- IS

DIFFERENT 3D SHAPES AND ENERGIES

e^- IS NO LONGER IN DEFINED CIRCULAR ORBITS BUT IN "FUZZY" ORBITALS

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THESE DESCRIBE ALL ATOMS AND THEIR SPECTRA

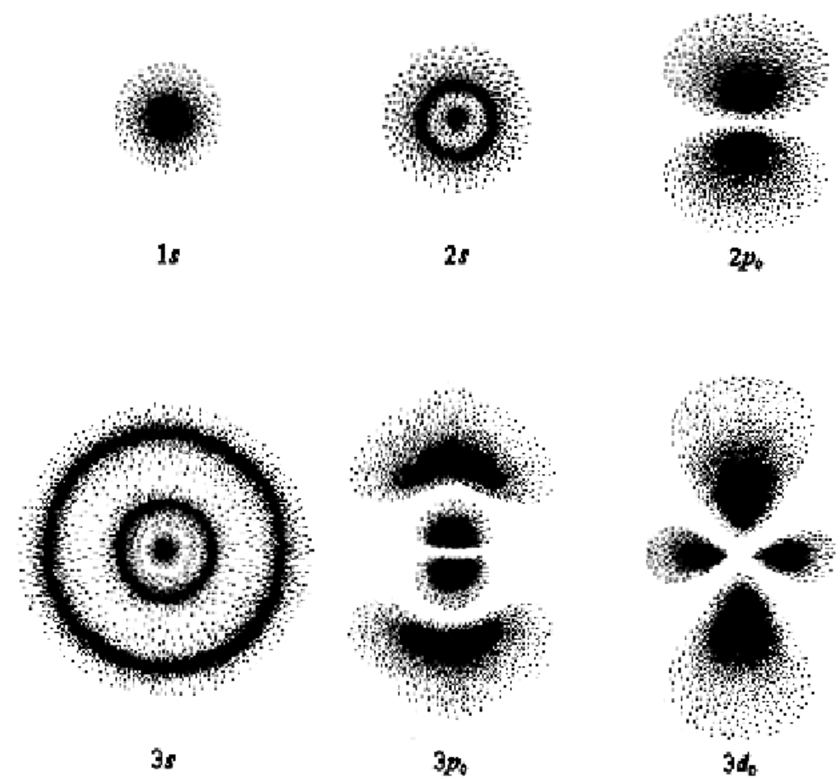
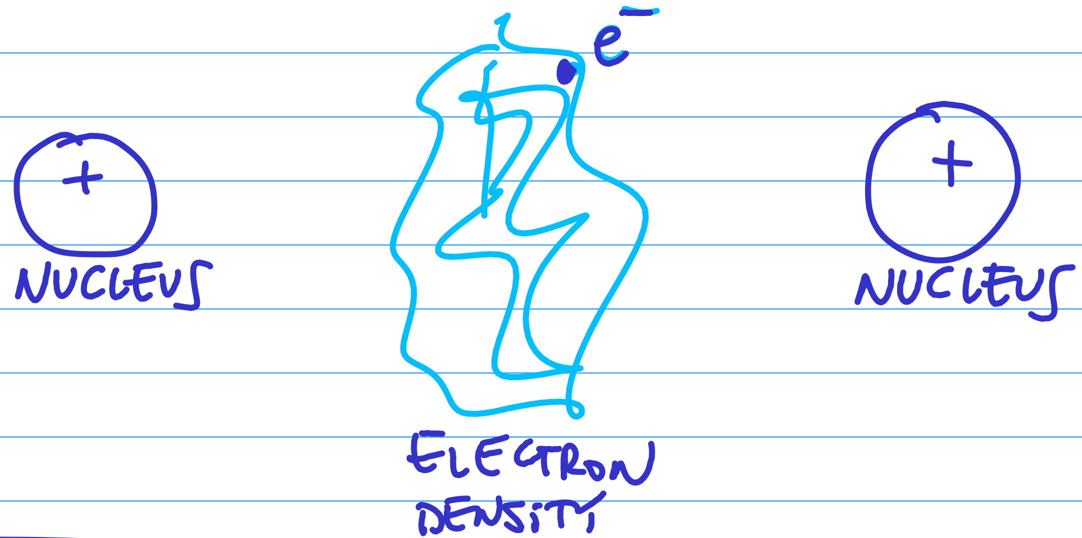
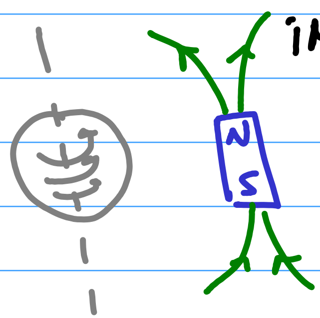


Figure 6-12. Probability density plots of some hydrogen atomic orbitals. The density of the dots represents the probability of finding the electron in that region.

IN FACT, TO UNDERSTAND CHEMISTRY:
YOU HAVE TO UNDERSTAND HOW e^- ARE ARRANGED AMONG AVAILABLE QUANTUM STATES.



SPIN: SPIN IS A FUNDAMENTAL PROPERTY OF NATURE LIKE CHARGE OR MASS.

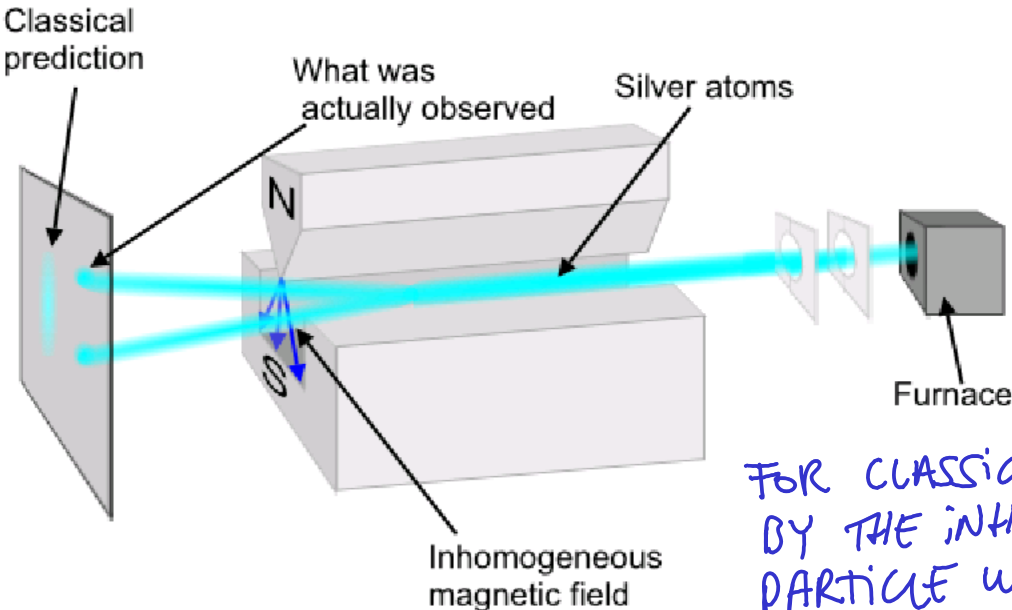


IMAGINE e^- AS A SPINNING BALL OF CHARGE

SPINNING CHARGE CREATES A MAGNETIC FIELD

STERN-GERLACH DISCOVERED THAT PARTICLES CAN ACT LIKE LITTLE MAGNETS: THEY HAVE SPIN

Stern-Gerlach Experiment 1922



Otto Stern vowed in 1913:

"If this nonsense of Bohr should in the end prove to be right, we will quit physics!"

-Article in Physics Today, December 2003

FOR CLASSICAL "SPINNING" PARTICLES: THE DEFLECTION BY THE INHOMOGENEOUS B FIELD IS RANDOM, EACH PARTICLE WILL BE DEFLECTED UP OR DOWN BY SOME AMOUNT ⇒ EVEN DISTRIBUTION ON SCREEN/DETECTOR.

THE FACT THAT THE ATOMS WERE DEFLECTED IN TWO DISTINCT DIRECTIONS (UP BY A FIXED AMOUNT, OR DOWN BY A FIXED AMOUNT) MEANS THAT SPIN IS QUANTIZED AND ONLY HAS TWO POSSIBLE VALUES: "UP" OR "DOWN".

SPIN IS QUANTIZED

THINK OF PARTICLES AS MAGNETS OF SELECTED STRENGTHS ... MULTIPLE OF $1/2$ → VALUE FOR e^-

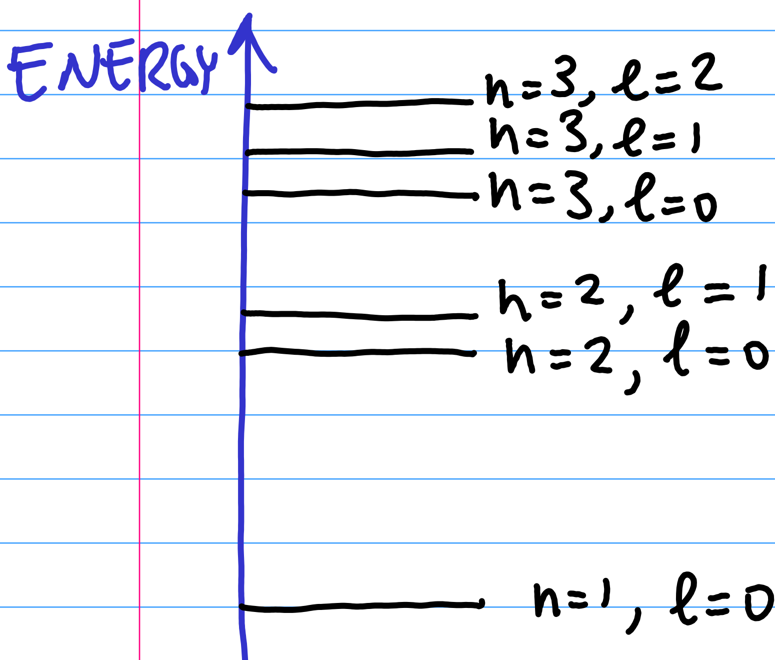
SPIN: $0, \frac{1}{2}, 1, \frac{3}{2}, 2 \ldots$

ALL PARTICLES ARE DIVIDED INTO :

BOSONS : INTEGER SPINS (0, 1, 2, 3 ...)

FERMIONS : $\frac{1}{2}$ INTEGER SPINS ($1/2$, $3/2$, $5/2$, ...)

2 BOSONS CAN OCCUPY THE SAME QUANTUM STATE
2 FERMIONS CANNOT " " " "

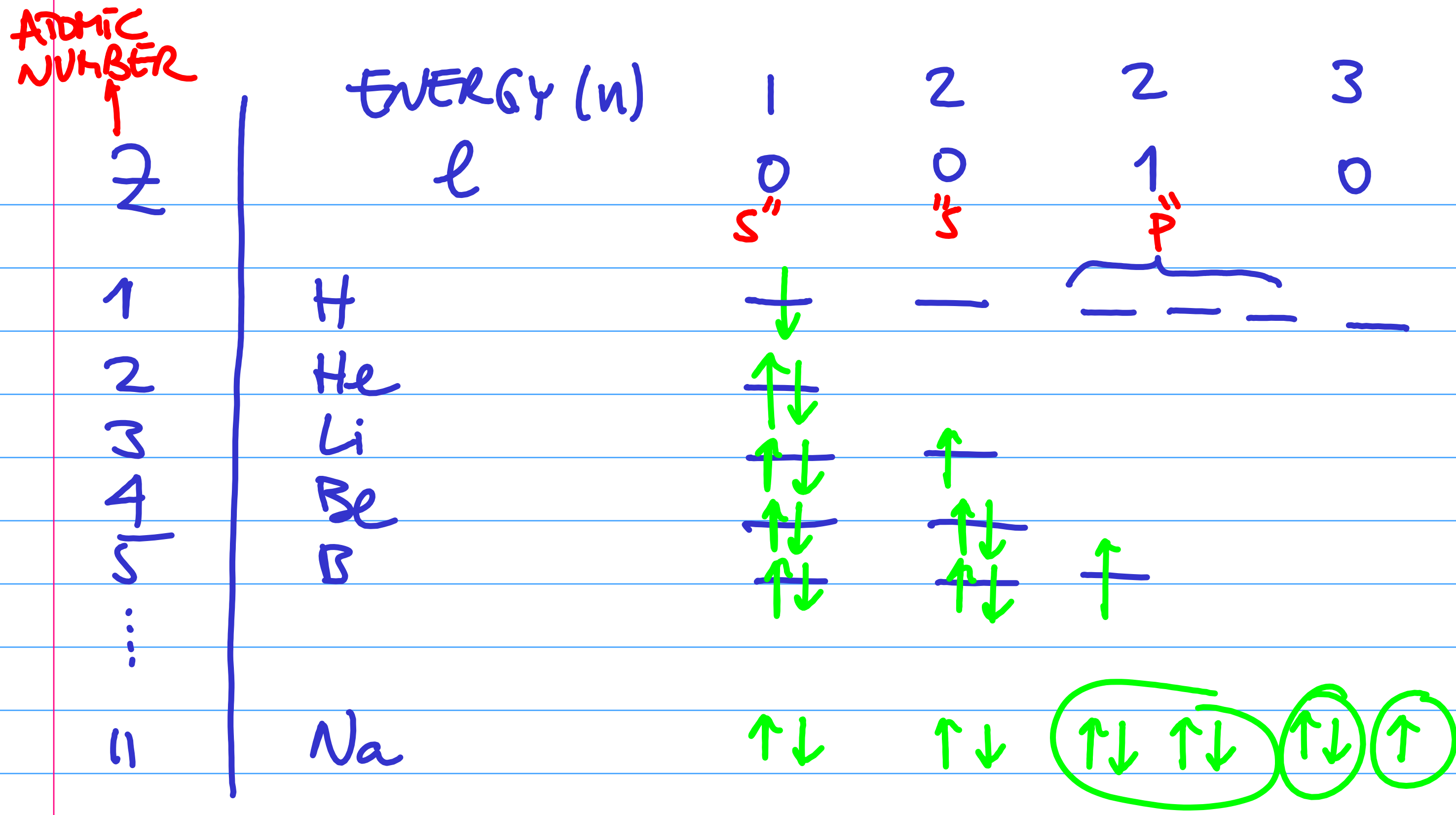


ALLOWED ENERGIES : "QUANTUM STATES" FROM SCHRÖDINGER EQN.

FOUR QUANTUM NUMBERS DETERMINE ONE "STATE" :

n = PRINCIPAL Q. NUMBER → E
ℓ = AZIMUTHAL Q. NUMBER → SHAPE
m_ℓ = MAGNETIC Q. NUMBER → ORIENTATION
m_s = SPIN

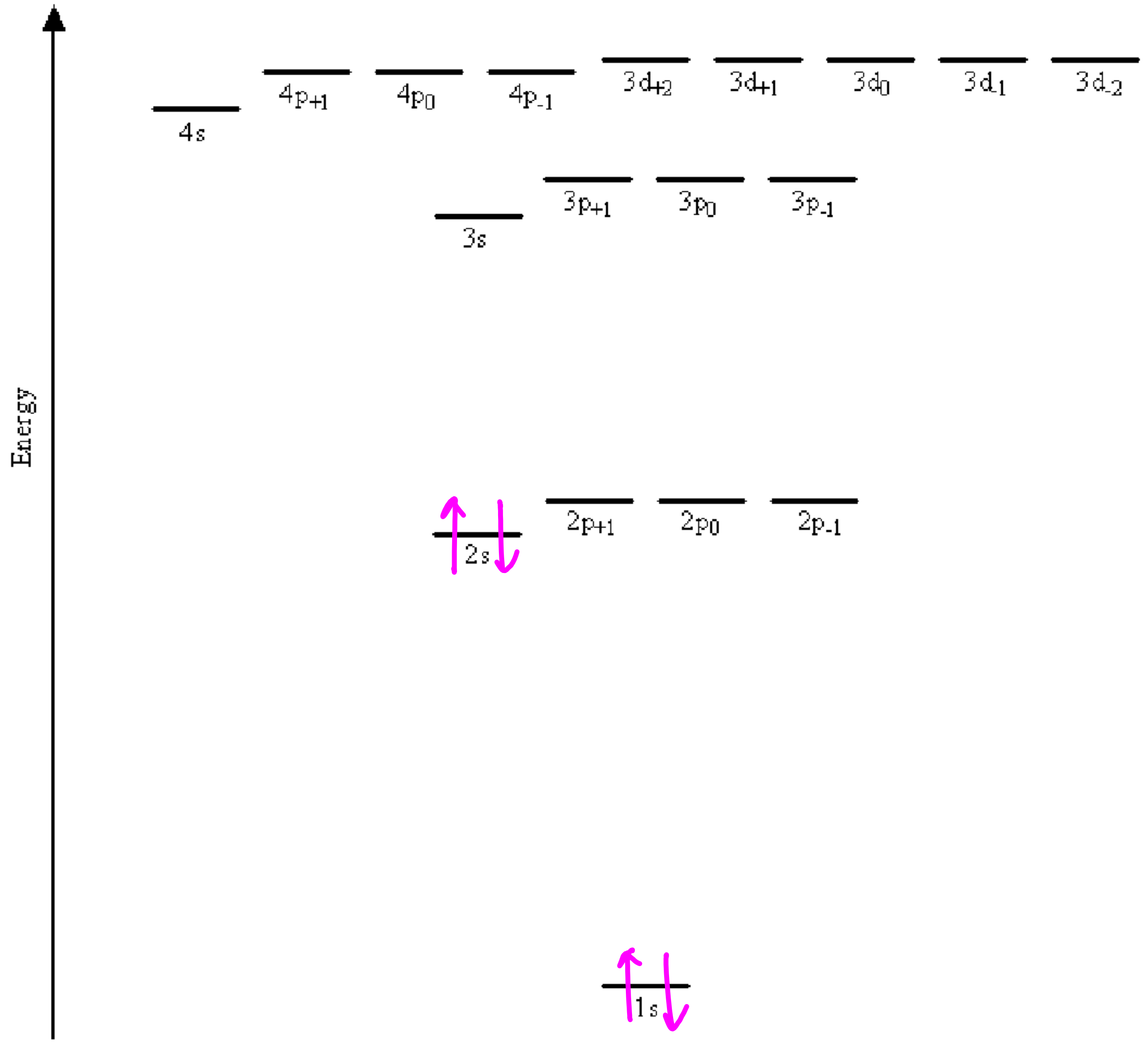
e^- CAN OCCUPY ONLY THESE Q. STATES



Z IS THE ATOMIC NUMBER : NUMBER OF PROTONS IN THE NUCLEUS

AS Z INCREASES, SO DOES THE NUMBER OF e^-

FILL AVAILABLE QUANTUM LEVELS FROM LOWEST TO HIGHEST


Energy
4s
4p+1
4p0
4p-1
3d+2
3d+1
3d0
3d-1
3d-2
3s
3p+1
3p0
3p-1
2s
2p+1
2p0
2p-1
1s