

Atoms & Matter



Lecture 2, Oct. 6

Astronomy 102, Autumn 2009

Atoms & Matter



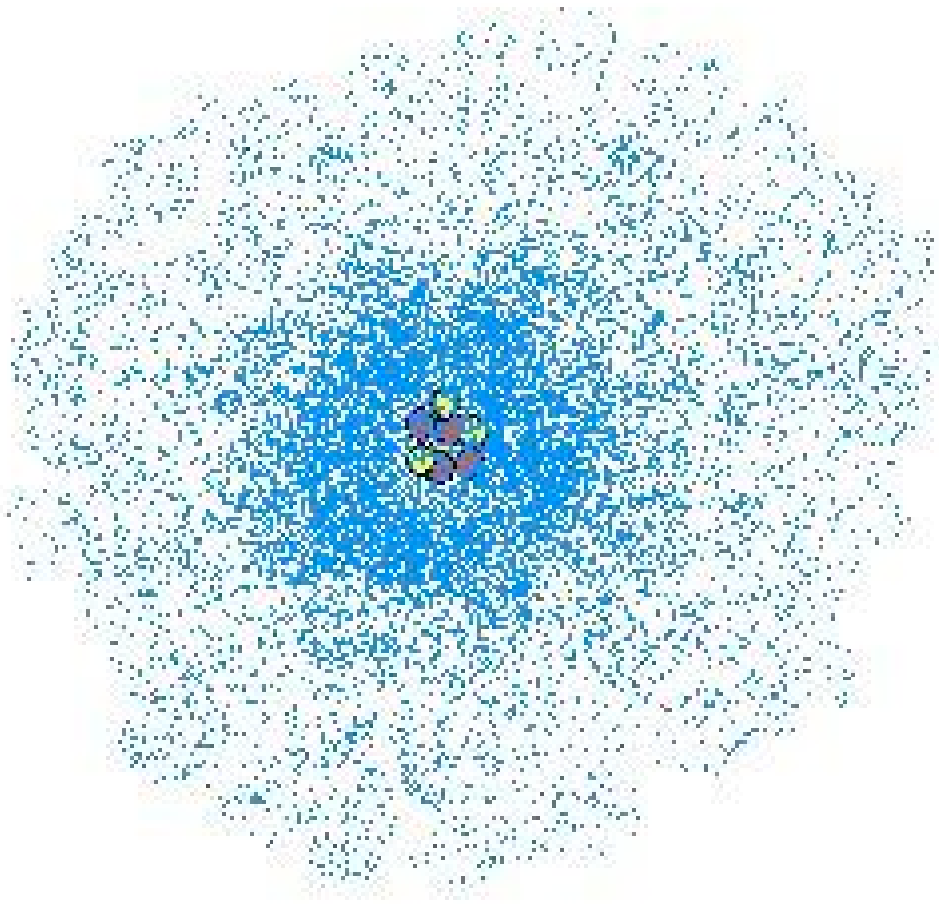
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Questions of the Day

- What is the structure of an atom?
- How do elements differ from each other?
- What are the four basic states of matter?
- How do they depend upon temperature?
- What is the condition of atoms in the various states of matter?

I. The basic building block of normal matter is the atom

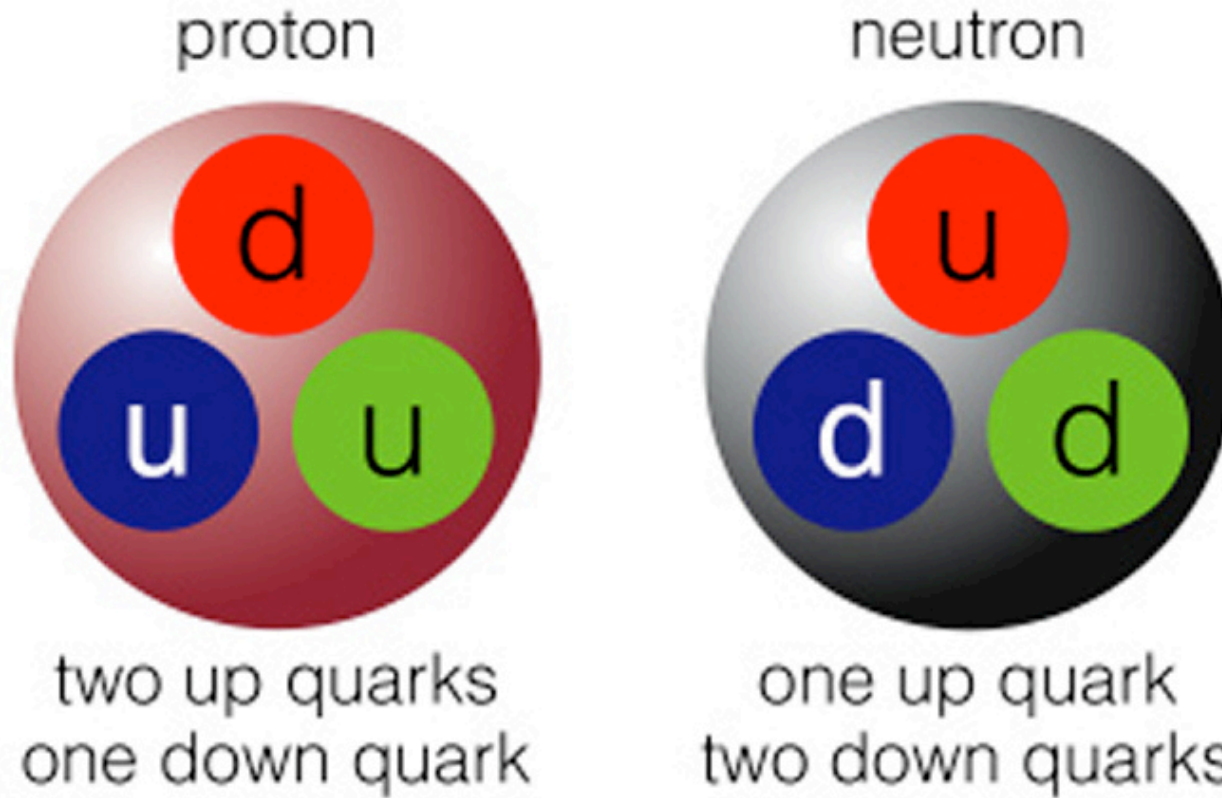


1. Electrons
 - Small Mass
 - Negative (-1) charge
2. "Up" quarks
 - Massive
 - Positive (+2/3) charge
3. "Down" quarks
 - Massive
 - Negative (-1/3) charge

Not drawn to scale!

Quarks (“subatomic particles”)

Give protons & neutrons their mass and charge.



As far as we know, quarks & electrons are the fundamental building blocks of matter!

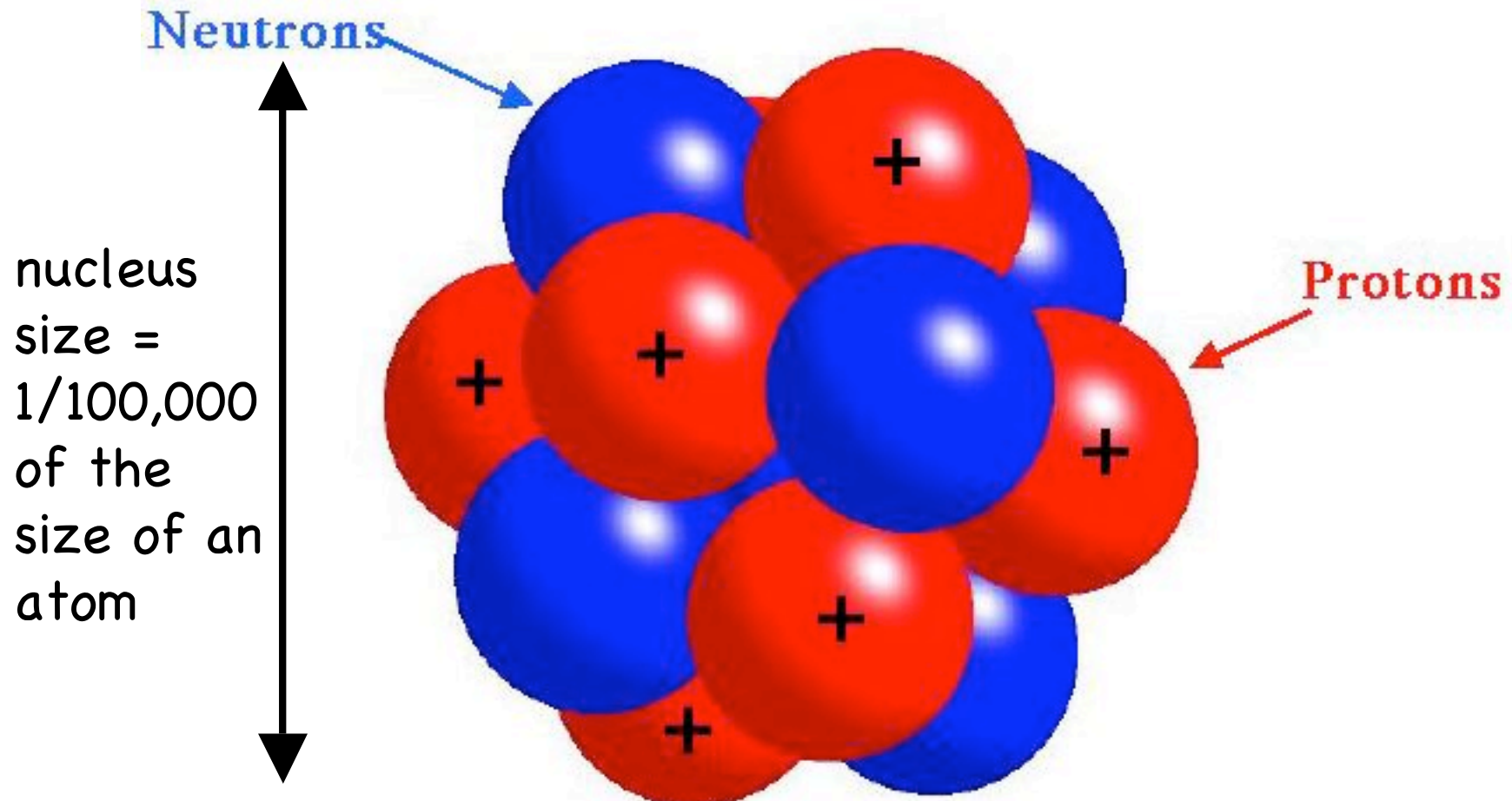
Murray Gell Mann (1929-)

- Avid linguist & physicist
- Went to Yale at 15!
- "Quark" came from James Joyce's Finnegan's Wake
- He likes whimsical names: "Eightfold Way," "up, down, strange quarks," "Color charge," "gluons," "plectics," ...

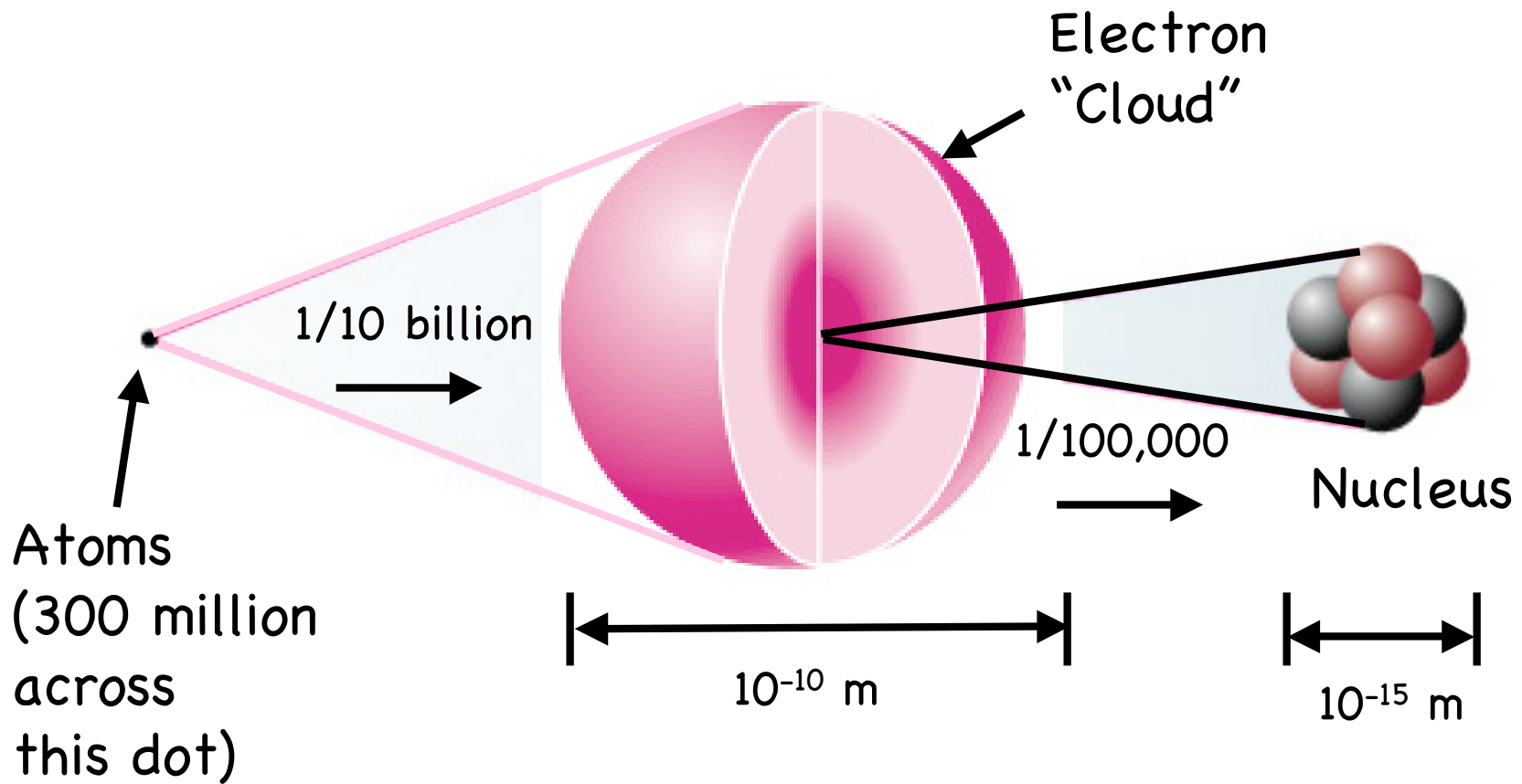


The Nucleus

- Protons and Neutrons have almost the same mass.
- They are tiny in size
- Held together by the “strong” nuclear force

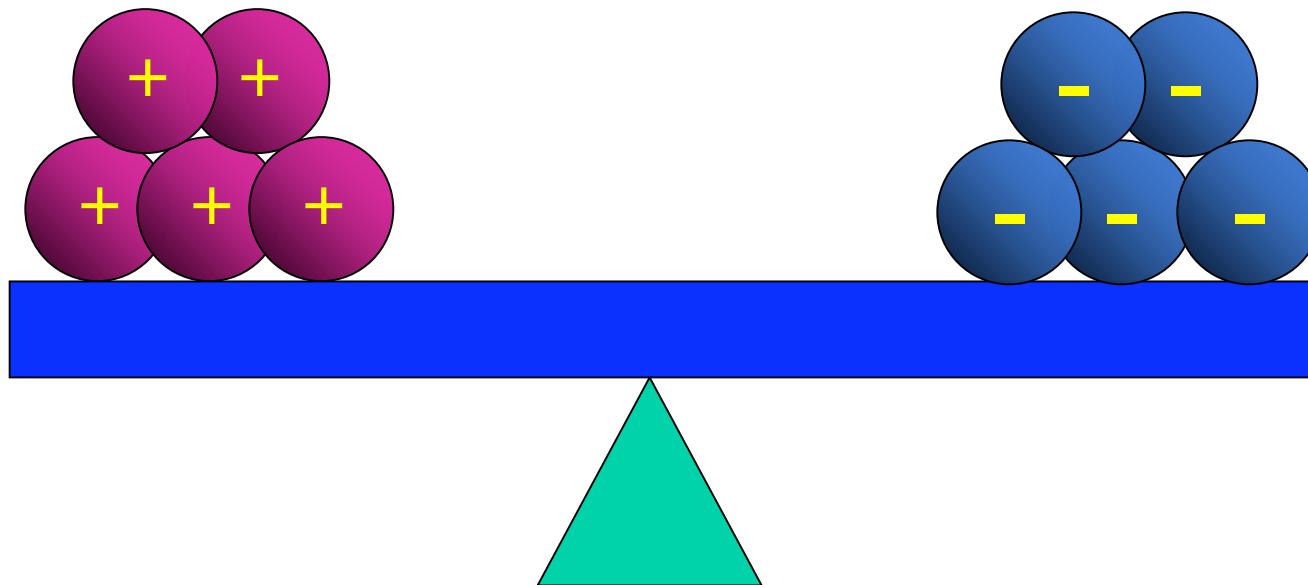


The structure an atom:




II. The basic rules of atoms

- a) An atom wants to have as many electrons as protons (i.e. it wants to be electrically **NEUTRAL**, with no net charge)



b) The number of protons strongly defines how the atom behaves chemically.

of protons  **ELEMENT**

"Atomic Number"	1	Hydrogen
	2	Helium
	6	Carbon
	8	Oxygen
	26	Iron

The Periodic Table

	IA																			0	
1	1 H																				2 He
2	3 Li	4 Be										5 B	6 C	7 N	8 O	9 F	10 Ne				
3	11 Na	12 Mg										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	57 *La	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	89 +Ac	104	105	106	107	108	109	110	111	112		114		116		118			

*Lanthanide Series	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	71 Lu
+Actinide Series	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	103 Lr

Each box is a different element, with a different number of protons.

The Periodic Table

The Periodic Table of Dessert

S 3.8 Sugar															B 7.2 Butter			
M 3.0 Honey	Sa 0 Salt													Ai 0 Air	F 3.6 Flour	V 2.8 Vanilla	O 1.5 Egg	Lt 0.61 Milk
Cs 2.8 Corn Syrup	Ci - Cinnamon													Gl 0 Ice	Oa 3.7 Oatmeal	C 5.0 Chocolate	So 0 Baking Soda	Cr 3.5 Cream
Sm 2.9 Sorghum	N - Nutmeg	Pn 6.9 Pecan	Ar 5.8 Cashew	Pi 5.7 Pistachio	Fi 6.3 Hazelnut	W 6.5 Walnut	Mc 7.2 Macadamia	Ct 2.4 Chestnut	Al 5.8 Almond	P 5.9 Peanut Butter	Cc 2.3 Coconut Milk							
Ms 2.6 Maple Syrup	Cl - Clove	Cf - Coffee	Mi - Mint	An - Anise	Lc - Licorice	Ps 5.3 Poppy Seed	Ti 5.9 Tahini	Ta 3.6 Tapioca	Mp 4.6 Marzipan	Ge 3.6 Gelatin	Vs 8.8 Shortening							
Bs 3.7 Brown Sugar	Ca - Cardamom	Cn 3.5 Candied Citron	Dt 2.7 Date	Pr 2.4 Prune	R 3.0 Raisin	Fg 2.6 Fig	Mm 2.9 Mincemeat	Rh 0.21 Rhubarb	Pu 0.2 Pumpkin	Mw 3.2 Marsh-mallow	La 9.0 Lard							
Mo 2.3 Molasses	G - Ginger													Fc 0 Food Coloring	Dr 3.8 Little Silver Balls	J 3.9 Sprinkles	Gc 4.2 Icing	Ri 1.7 Ricotta



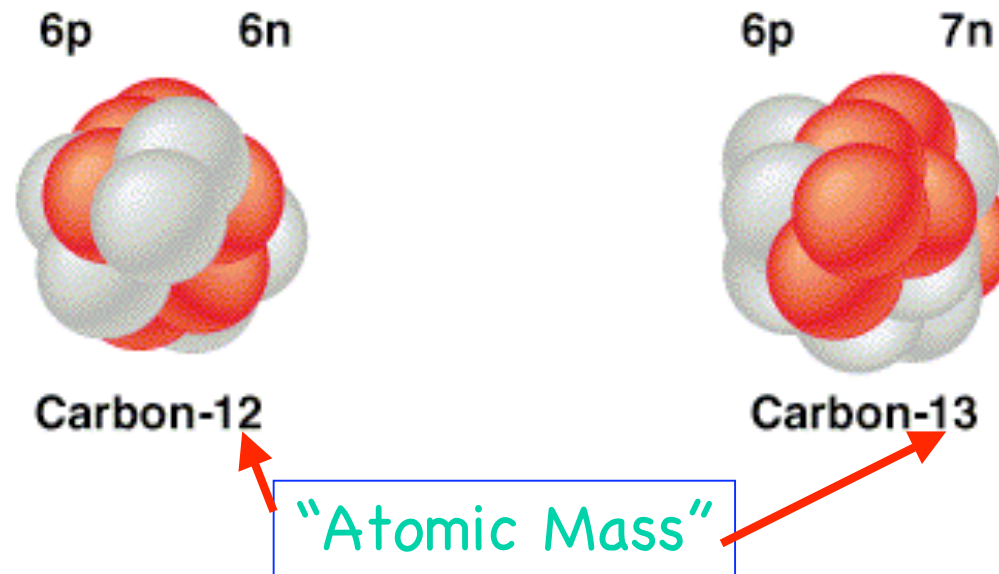
L 0.29 Lemon	Li 0.30 Lime	Or 0.47 Orange	A 0.58 Apple	Ba 0.92 Banana	At 0.49 Apricot	Rb 0.49 Raspberry	Bb 0.56 Blueberry	Ce 0.72 Cherry	Sb 0.30 Strawberry
Ma 1.5 Marsala	To 1.5 Tokay	Br 2.4 Brandy	Wh 2.5 Whiskey	Bn 2.5 Bourbon	Rm 2.3 Rum	Gm 2.4 Grand Marnier	Cm 3.7 Crème de Menthe	Fr 1.5 Frangelico	Co 1.5 Crème de Cacao

Andrew Plotkin C2003

c) Neutrons add mass, but don't change much about how the atom behaves

of neutrons

Same element, but different isotopes.

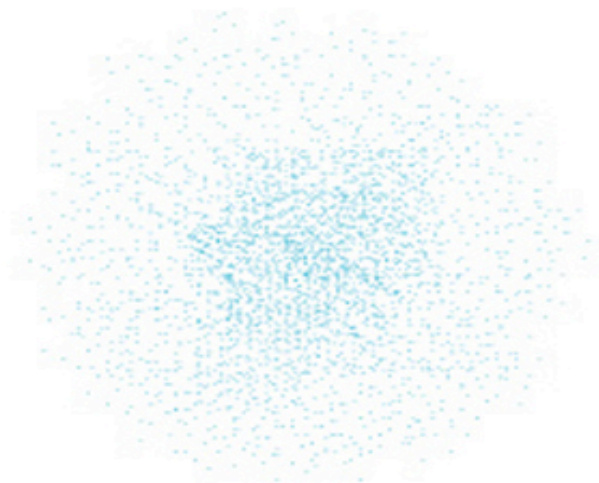


d) The structure of the electrons is affected by the energy of the atom.

Low
energy →
electrons
close in.



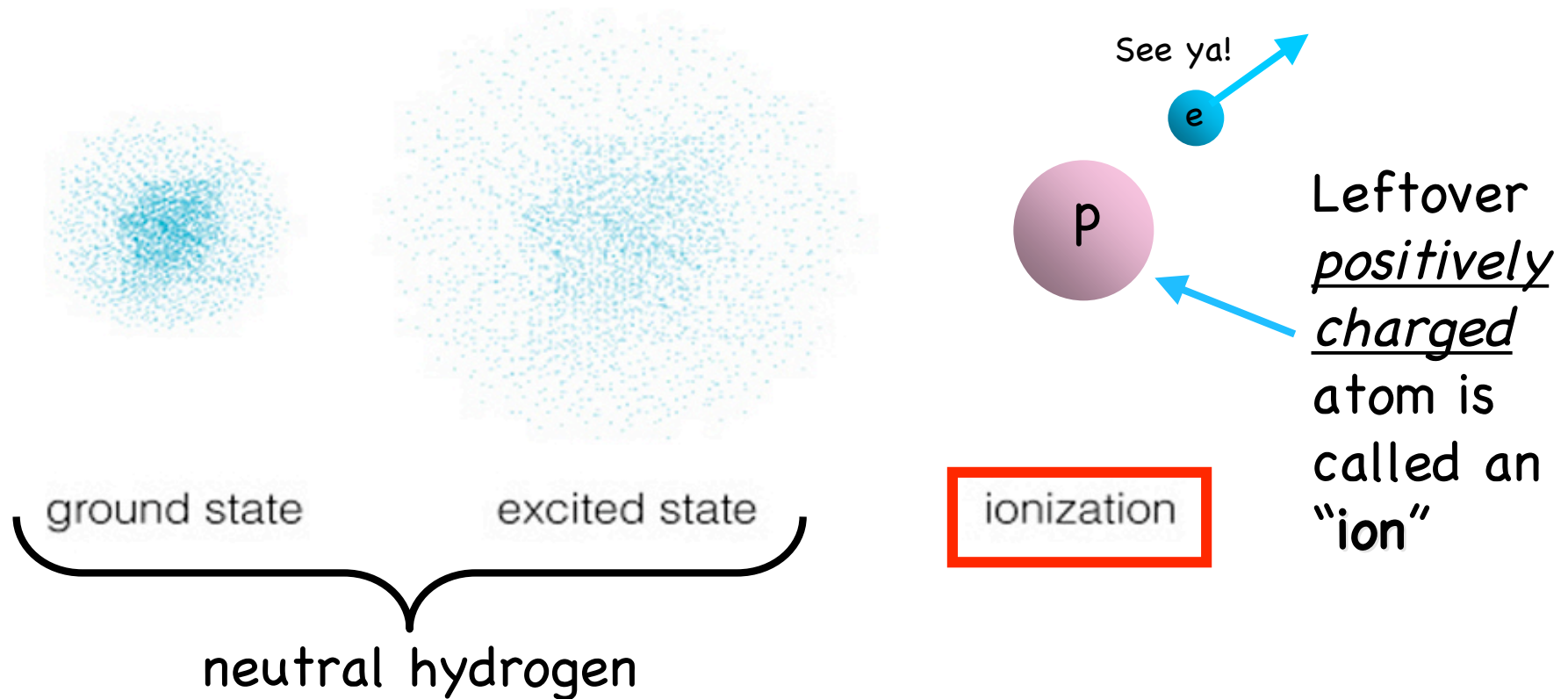
ground state



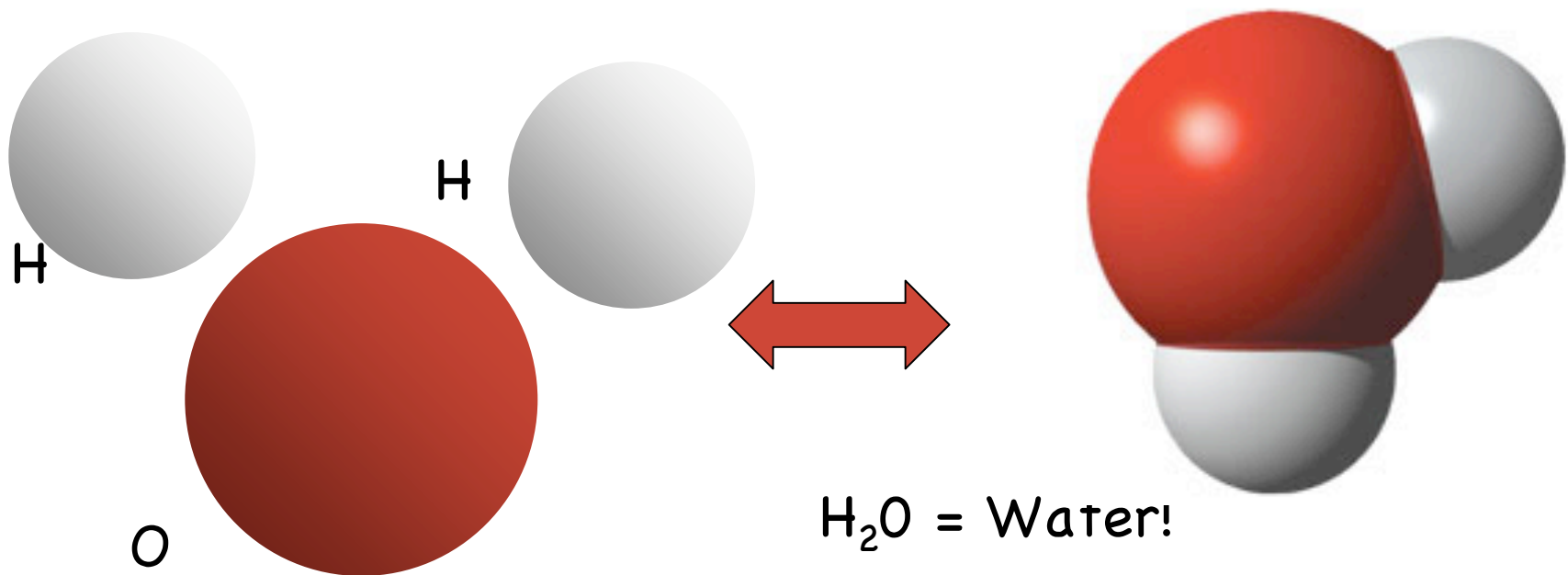
excited state

High
energy →
electrons
further
out.

e) Highly energetic electrons can be stripped from the atom: "Ionization"



f) Atoms combine to form **molecules** by sharing electrons, but the nuclei don't interact (usually).



Question 1:

An ordinary atom of Helium has 2 protons + 2 neutrons in its nucleus.

An atom with: 2 protons is:
 1 neutrons
 2 electrons

- A. Neutral Helium
- B. Ionized Helium
- C. A neutral isotope of Helium
- D. An ionized isotope of Helium
- E. An element other than Helium

Question 2:

An ordinary atom of Helium has 2 protons + 2 neutrons in its nucleus.

An atom with: 3 protons is:
 2 neutrons
 2 electrons

- A. Neutral Helium
- B. Ionized Helium
- C. A neutral isotope of Helium
- D. An ionized isotope of Helium
- E. An element other than Helium

Question 3:

An ordinary atom of Helium has 2 protons + 2 neutrons in its nucleus.

An atom with: 2 protons is:
 2 neutrons
 1 electrons

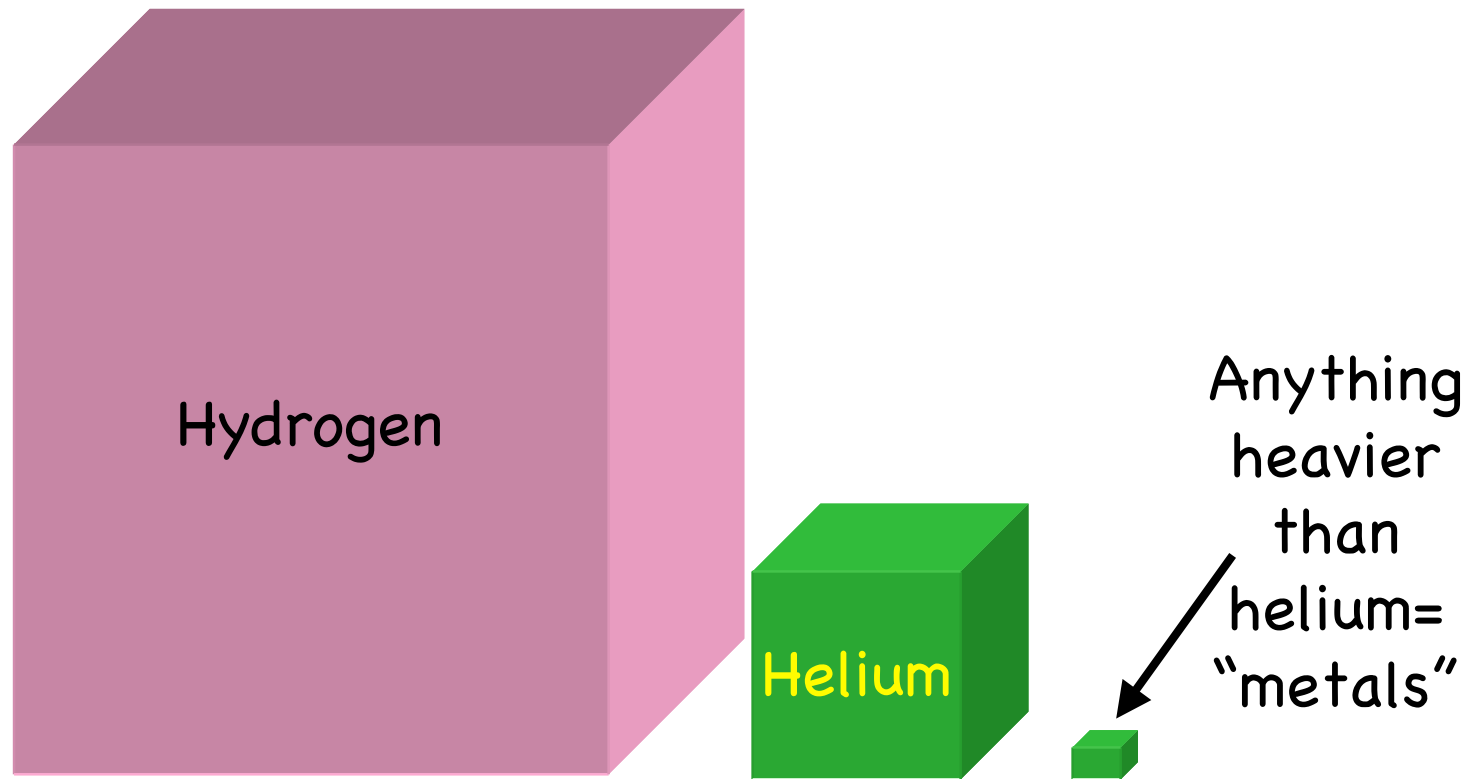
- A. Neutral Helium
- B. Ionized Helium
- C. A neutral isotope of Helium
- D. An ionized isotope of Helium
- E. An element other than Helium

Elements, Atoms, & Molecules:

Why are they important?

- universe is made of elements, atoms, and/or molecules → raw material for planets, stars, & galaxies
- Almost all *light* in the universe is generated through processes related to elements, atoms, & molecules.

Of all the possible elements, the Universe is made up almost entirely of Hydrogen and Helium.



Of all the possible elements, the Universe is made up almost entirely of Hydrogen and Helium.

ELEMENT	PERCENTAGE BY NUMBER OF ATOMS	PERCENTAGE BY MASS
Hydrogen	92.0	73.4
Helium	7.8	25.0
Carbon	0.03	0.3
Nitrogen	0.008	0.1
Oxygen	0.06	0.8
Neon	0.008	0.1
Magnesium	0.002	0.05
Silicon	0.003	0.07
Sulfur	0.002	0.04
Iron	0.004	0.2

III. Elements occur in many different forms

a) Solids



← The surface of the moon, taken during the Apollo 17 mission.

Interstellar dust cloud →



b) Liquids (not much)

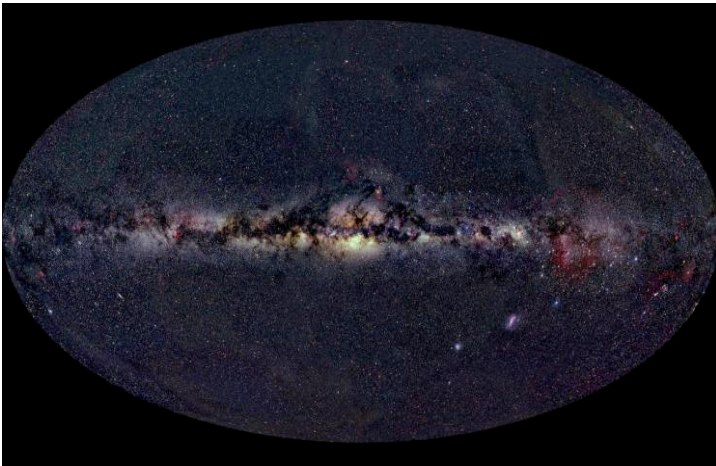


Oceans

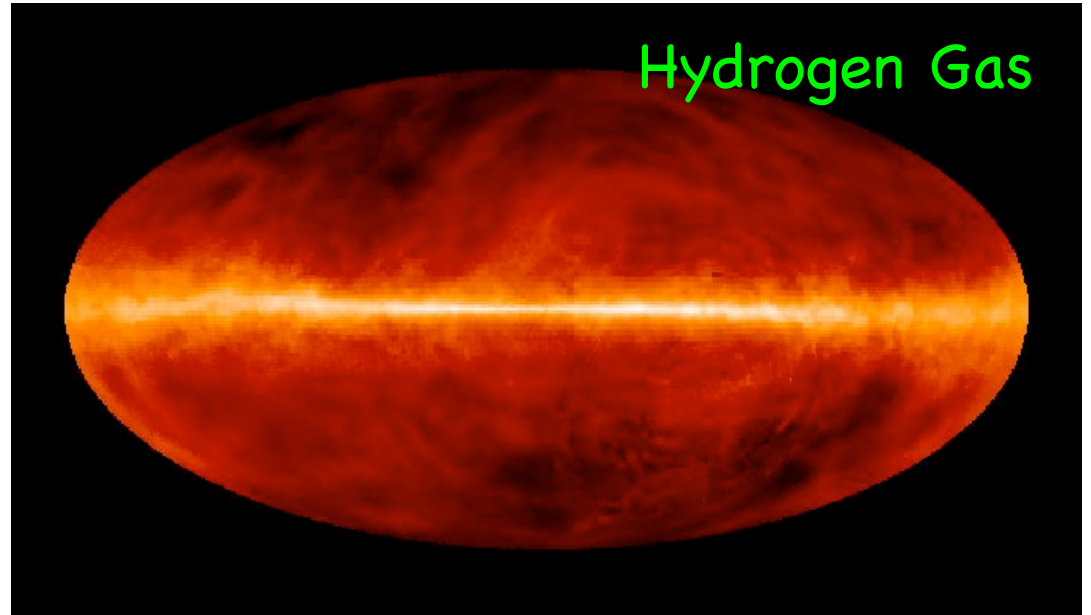


c) Gas (lots!)

Optical



Hydrogen Gas

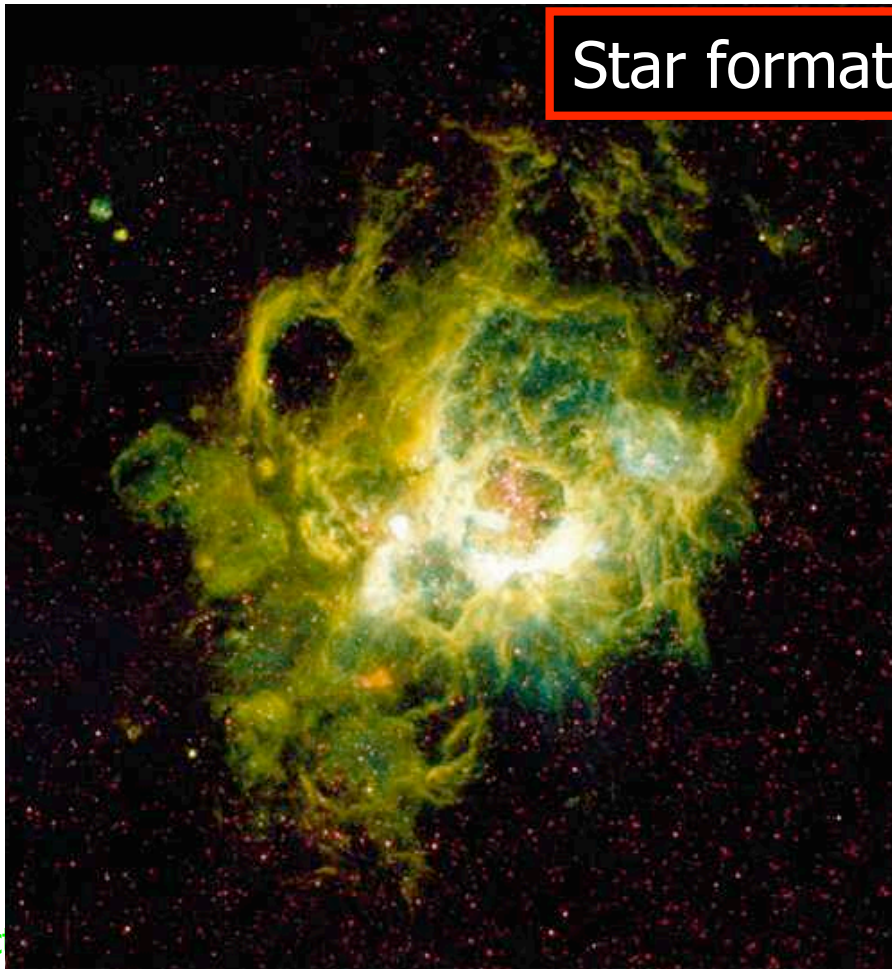


Milky Way Galaxy

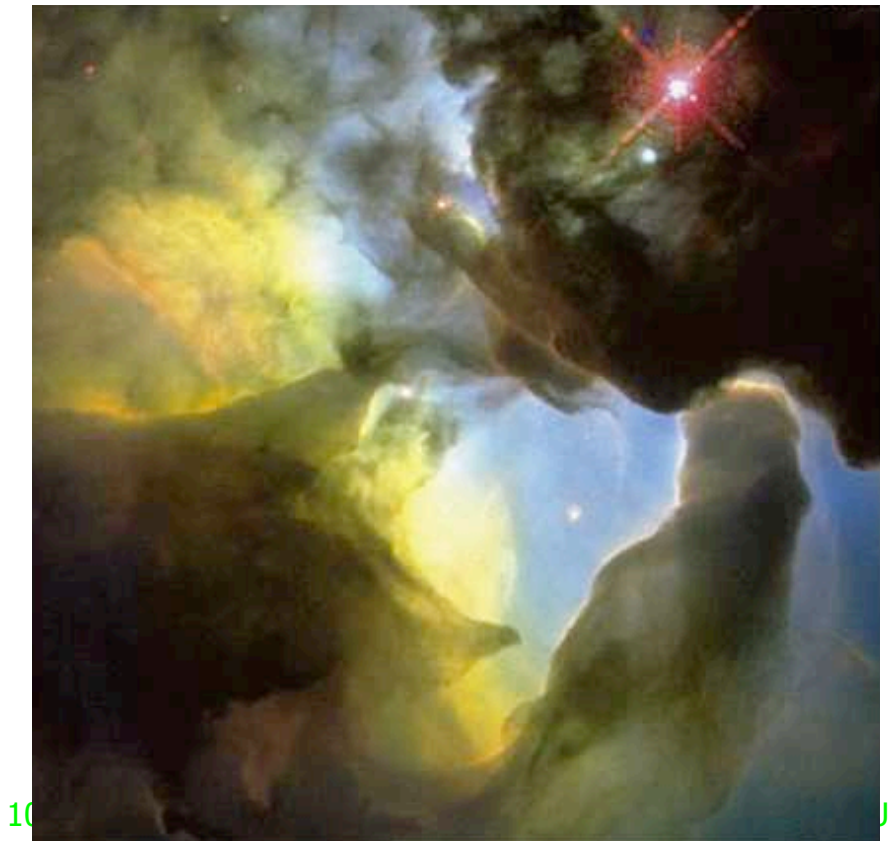
d) Plasma or ionized gas
(electrons are ripped from
atoms)



Star formation regions



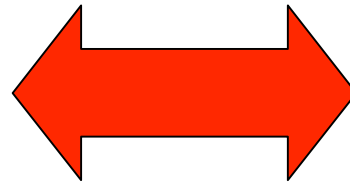
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J.W.

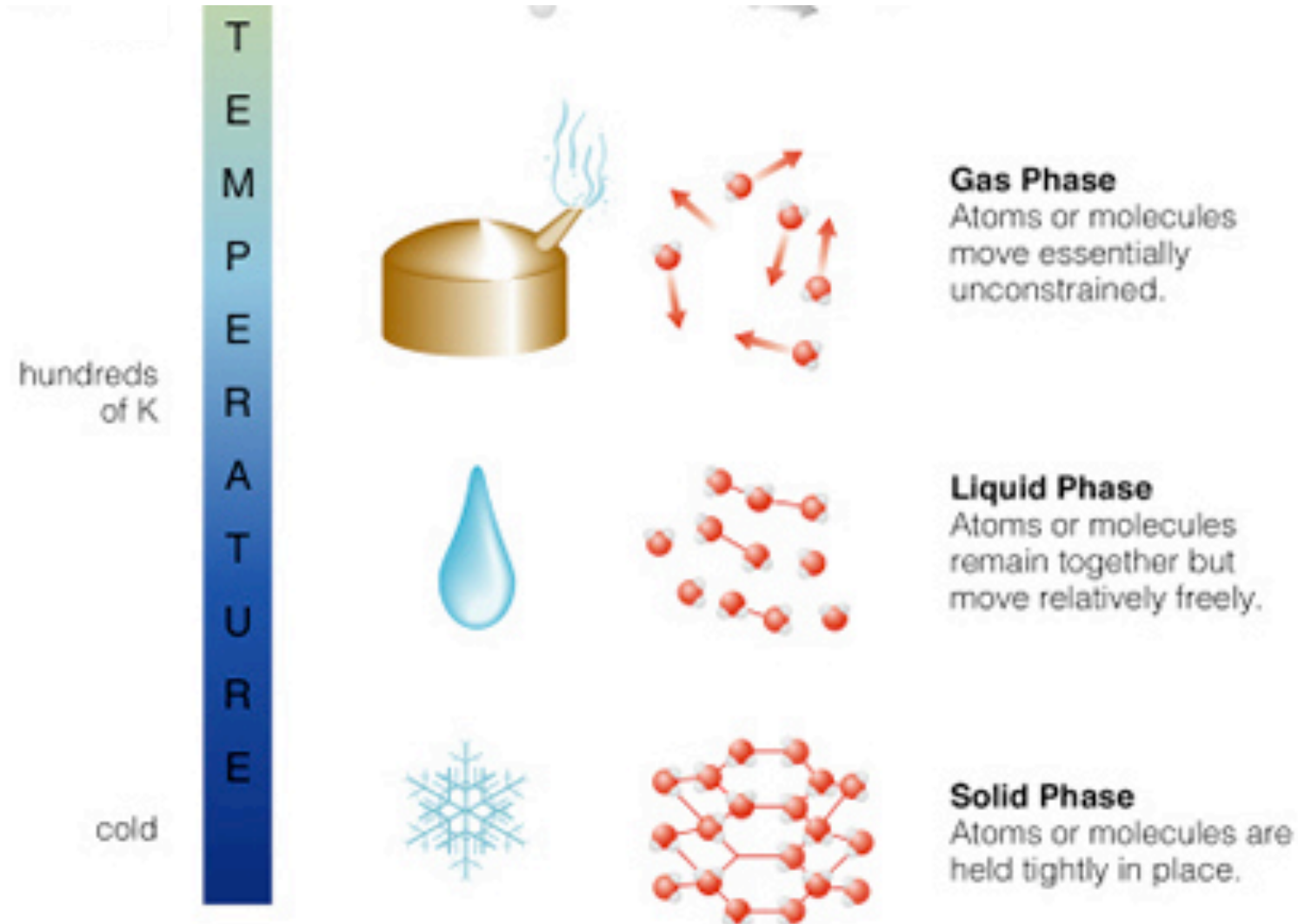
IV. How does temperature affect the state of matter?



Temperature alters the structure of the atoms and/or molecules.

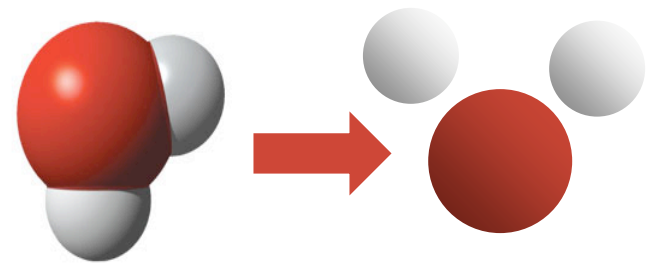
States of Matter

Temperature changes how closely atoms and molecules are bound to each other

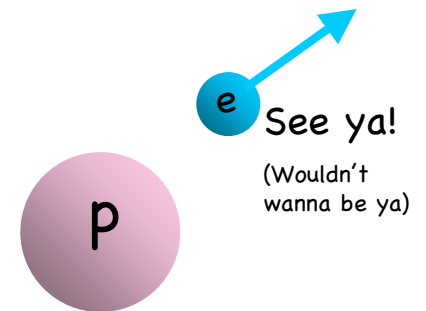


At extreme temperatures:

1. Molecules "dissociate"
= Atoms cannot remain
bound together



2. Atoms lose their electrons =
ionization = plasma



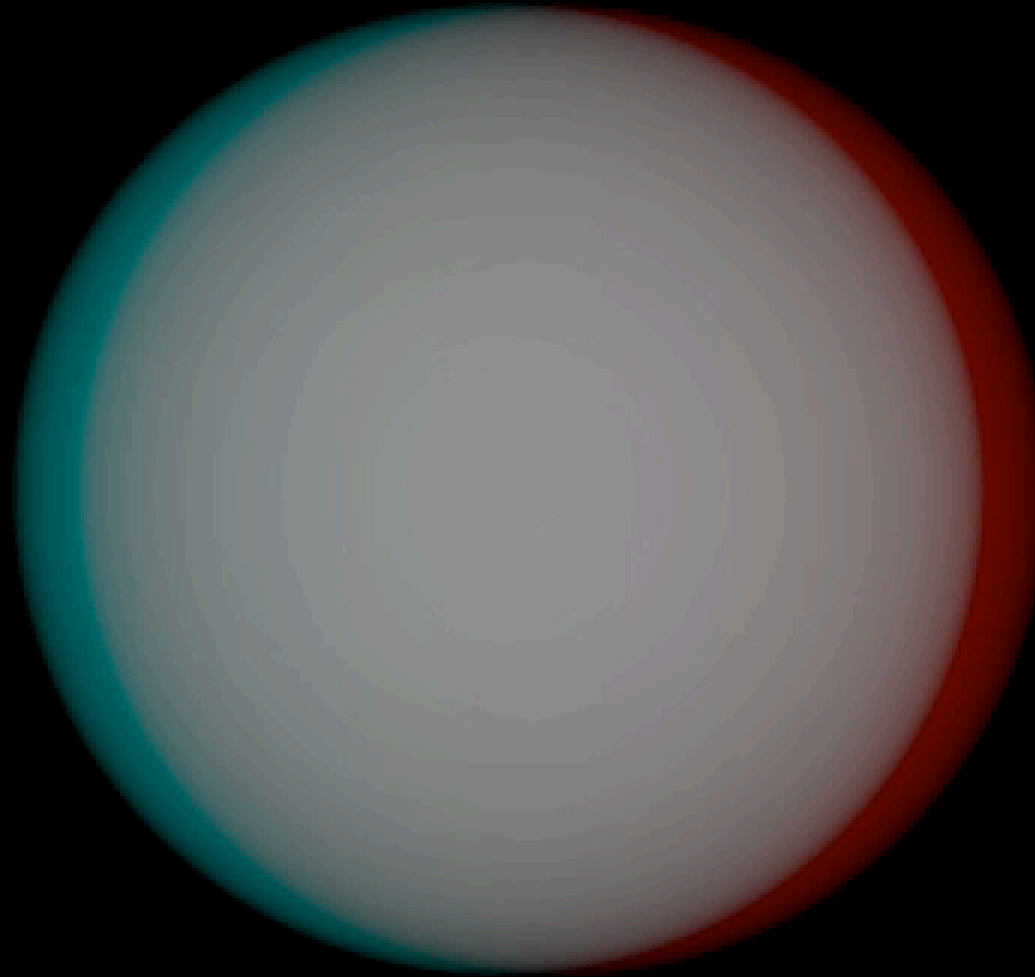
Note: These changes in “phase” do not take place at the exact same temperature for all materials



← Nitrogen is a liquid even when it's very cold (77 degrees above absolute zero = -321°F)

A saucepan is still solid even when water changes from liquid to gas →





Matthew Bate





Matthew Bate



Recap

- An atom is made of a nucleus (made of protons & neutrons) plus electron cloud
- Number of protons determines chemical element
- Number of neutrons -> isotope
- Number of electrons -> neutral or ion
- Atoms make up molecules - chemistry
- Solid, liquid, gas & plasma phases are determined by increasing temperature