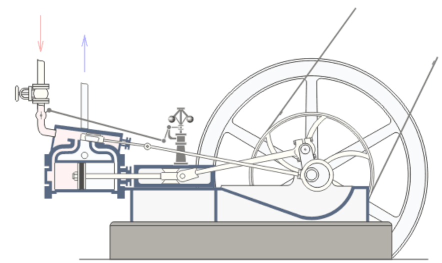
Chem 108

Introductory Chemistry

Dr. Ron Rusay

CONNECTIONS: Chemistry ⇆ STE(A)M

STE(A)M



S Science
T Technology
E Engineering
M Mathematics

< A: Arts & Applications

Chemistry Connections
(CHEM 108)

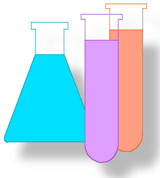
- STE(A)M ⇆ Chemistry ⇆ Allied Careers
  - *Linked by the Scientific Method*

Chemistry focuses on the study of

- *Energy & Matter:*
  Classification, Behavior & Properties

All Science, Technology, Arts & Engineering involves:

- *Observations & Measurements:*
  (Qualitative & Quantitative)
- *Applying metric & related units*



Chemistry ⇆ Physics ⇆ Engineering

The Scientific Method (A Unifying Practice)

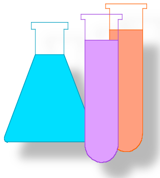
- *Energy & Matter: central in all three areas*
  eg. Forces & Gravity
- Observations: *Visible & Measureable*
- *Mathematics: Calculations & Models*

Progressions & Connections:

Arithmetic⇆Algebra⇆Calculus⇆Differential Equations⇆Partial Differential Equations⇆Linear Algebra⇆Non-linear Equations⇆Non-deterministic Systems

RESULTS: Protocols, Explanations, Predictions & Products

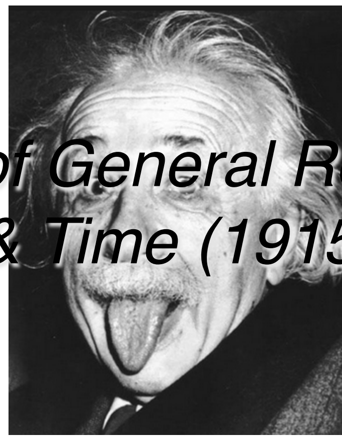
Examples: GPS, Cosmology, Space Travel, Space Probes,
New Materials: Structural, Mechanical, Industrial & Molecular



Law or Theory of Gravity?

Hipparchus and Erastothenes (~ 270 B.C.E.)

Galileo (~1600) & Isaac Newton (1687)



Theory of General Relativity: Space & Time (1915-2015)

The key idea of Einstein's theory of general relativity is that gravity is not an ordinary force, but rather a propert of space-time geometry.

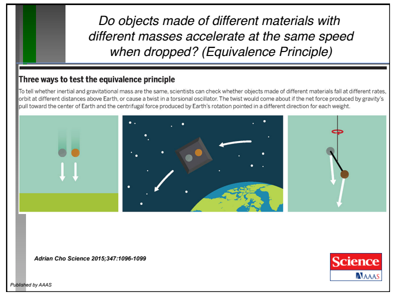
https://www.youtube.com/watch?v=wtsNOMTIS7E

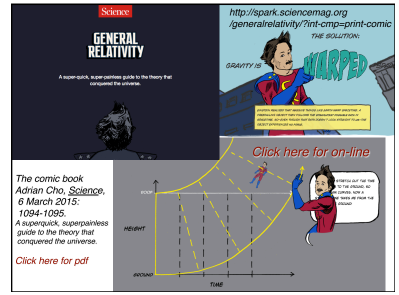
Which falls faster, a feather or a hammer?

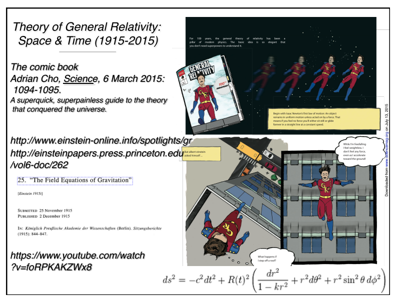
……. in a vacuum? …… on the moon?

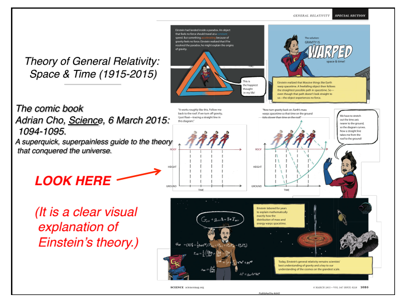
Chemistry ⇆ Physics

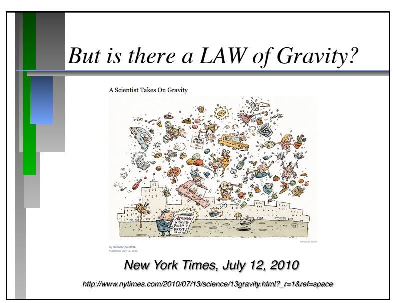
The Scientific Method (A Unifying Practice)

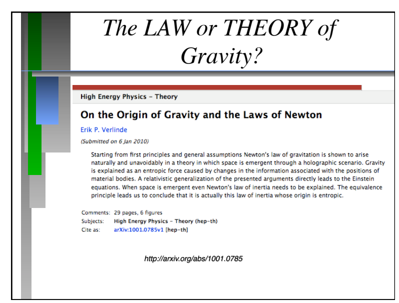










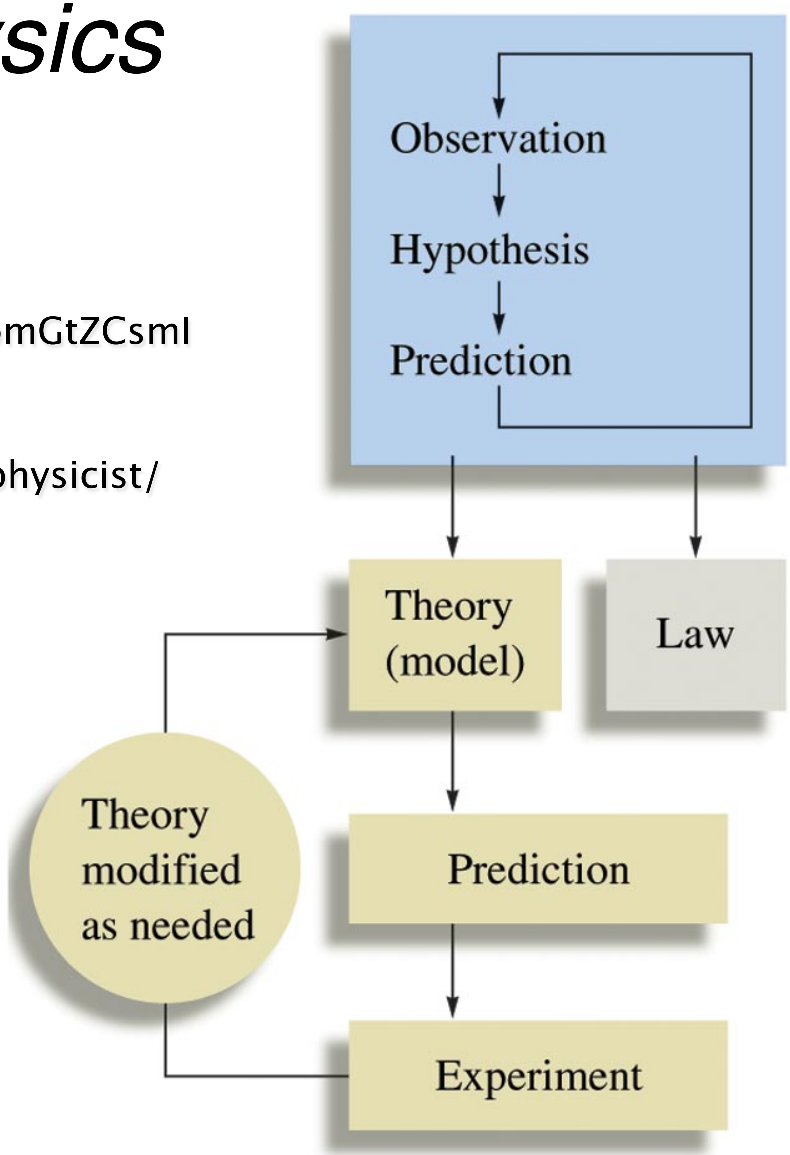


Chemistry ⇆ Physics

Law vs. Theory

[*A New Explanation of Gravity*](http://www.youtube.com/watch?v=vyomGtZCsmI)
http://www.youtube.com/watch?v=vyomGtZCsmI

[*The Case of Gravity*](http://www.science20.com/hammock_physicist/it_bit_case_gravity)
http://www.science20.com/hammock_physicist/it_bit_case_gravity



Law(s)? vs. Theory

Spinoza Prize €2.5 x 10^6

"The NWO Spinoza Prize is the highest Dutch award in science; that is awarded to Dutch researchers who rank among the absolute top of science."

QUESTION

Theories are best validated, proven or disproven by

A. *observations.*
B. *models.*
C. *laws.*
D. *experiments.*
E. *guesses.*

QUESTION

The difference between a scientific law and a scientific theory can, at times, be confusing. For example, we will refer to the "Atomic theory" or perhaps the "Law of Gravity." Should the Law of Gravity be changed to the Theory of Gravity?

A. Yes, no one can see gravity, it is better described as a theory.
B. No, scientific laws are based on summaries of many observations and gravity observations are well known and predictable. More than one theory may explain the observations.
C. Yes, gravity is better described as a theory because gravity explains why masses attract each other and theories are about explaining observations.
D. No, keep it as a law, laws offer explanations and gravity explains why masses attract each other and laws are about explaining observations.

Some Possible Steps in the Scientific Method

1. Observations
   - *qualitative (general, descriptive, subjective)*
   - *quantitative (numbers, values)*
2. Formulating hypotheses
   - *possible explanation(s) for the observation(s)*
3. Performing experiments
   - *gathering new information*
   - *testing whether the hypotheses are valid*
4. Developing a theory
5. Testing & Refining

QUESTION

Which statement most resembles a scientific theory?

A. *When the pressure of a sample of oxygen gas is increased 10%, the volume of the gas decreases by 10%.*

B. *The volume of an ideal gas doubles when the pressure of the gas is reduced by one half.*

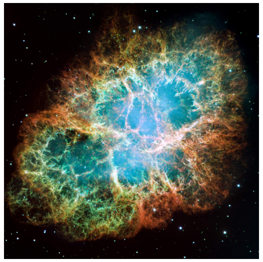
C. *Gases are composed of very small particles that are constantly moving. They collide with the surface of containers which hold them, producing pressure.*

D. *A gas sample has a mass of 15.8 grams and a volume of 10.5 Liters.*

Energy & Matter

$$E = mc^2$$

http://energy.gov/articles/livestream-our-latest-nobel-prize-winner

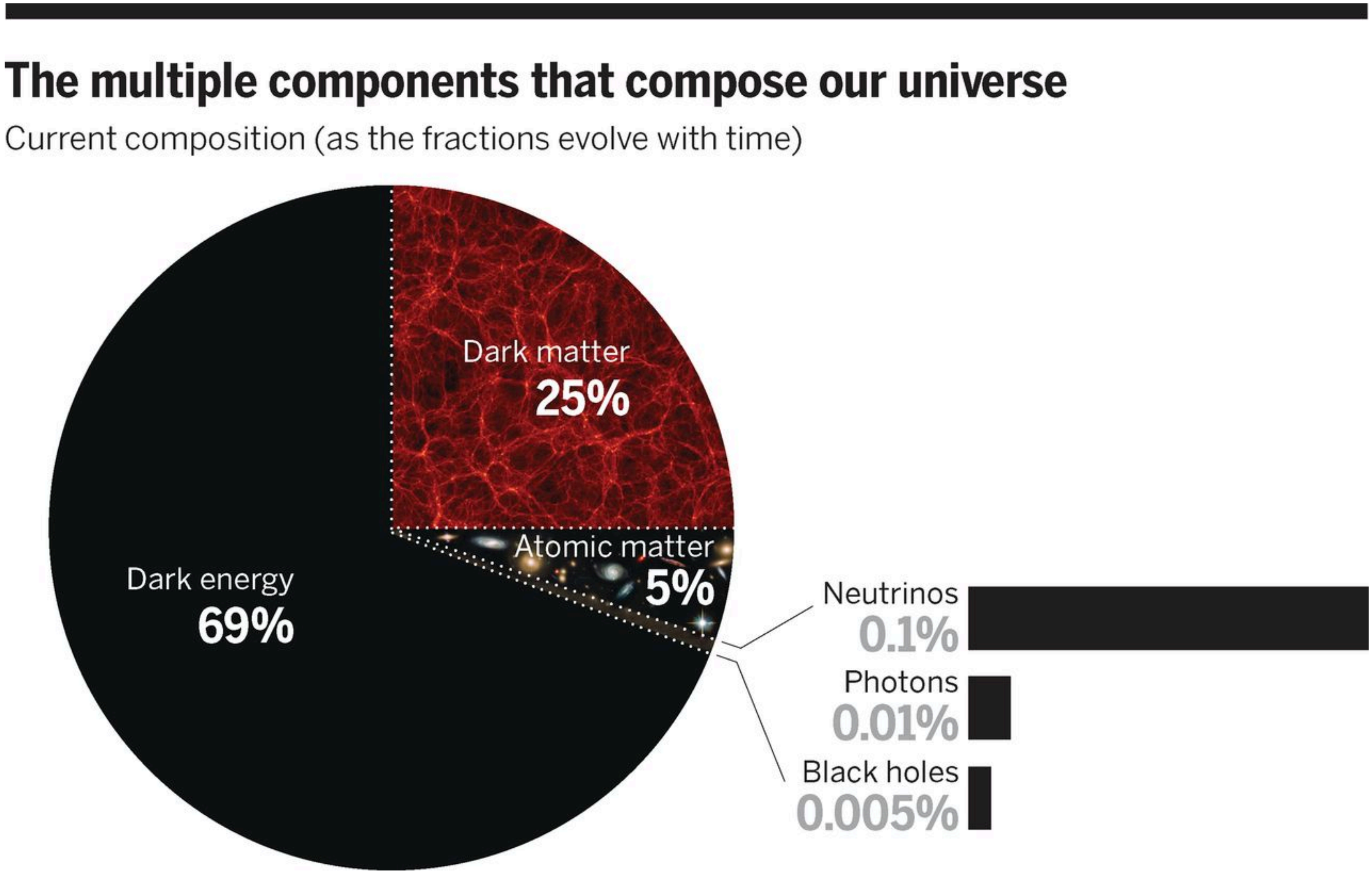


Based on the standard model of cosmology, the total mass/energy of the universe is comprised of 4.9% ordinary matter, 26.8% dark matter and 68.3% dark energy.[1][2] Thus, dark matter is estimated to constitute 84.5% of the total matter in the universe and 26.8% of the total content of the universe.[3]

Dark matter is matter that is undetectable by emitted or absorbed radiation, but whose presence can be inferred from gravitational effects.

1) Ade, P. A. R.; Aghanim, N.; Armitage-Caplan, C.; et al. (Planck Collaboration) (22 March 2013). "Planck 2013 results. I. Overview of products and scientific results – Table 9.". Astronomy and Astrophysics (submitted). arXiv:1303.5062. Bibcode:2013arXiv1303.5062P.
2) Francis, Matthew (22 March 2013). "First Planck results: the Universe is still weird and interesting". Arstechnica.
3) "Planck captures portrait of the young Universe, revealing earliest light". University of Cambridge. 21 March 2013. Retrieved 21 March 2013.

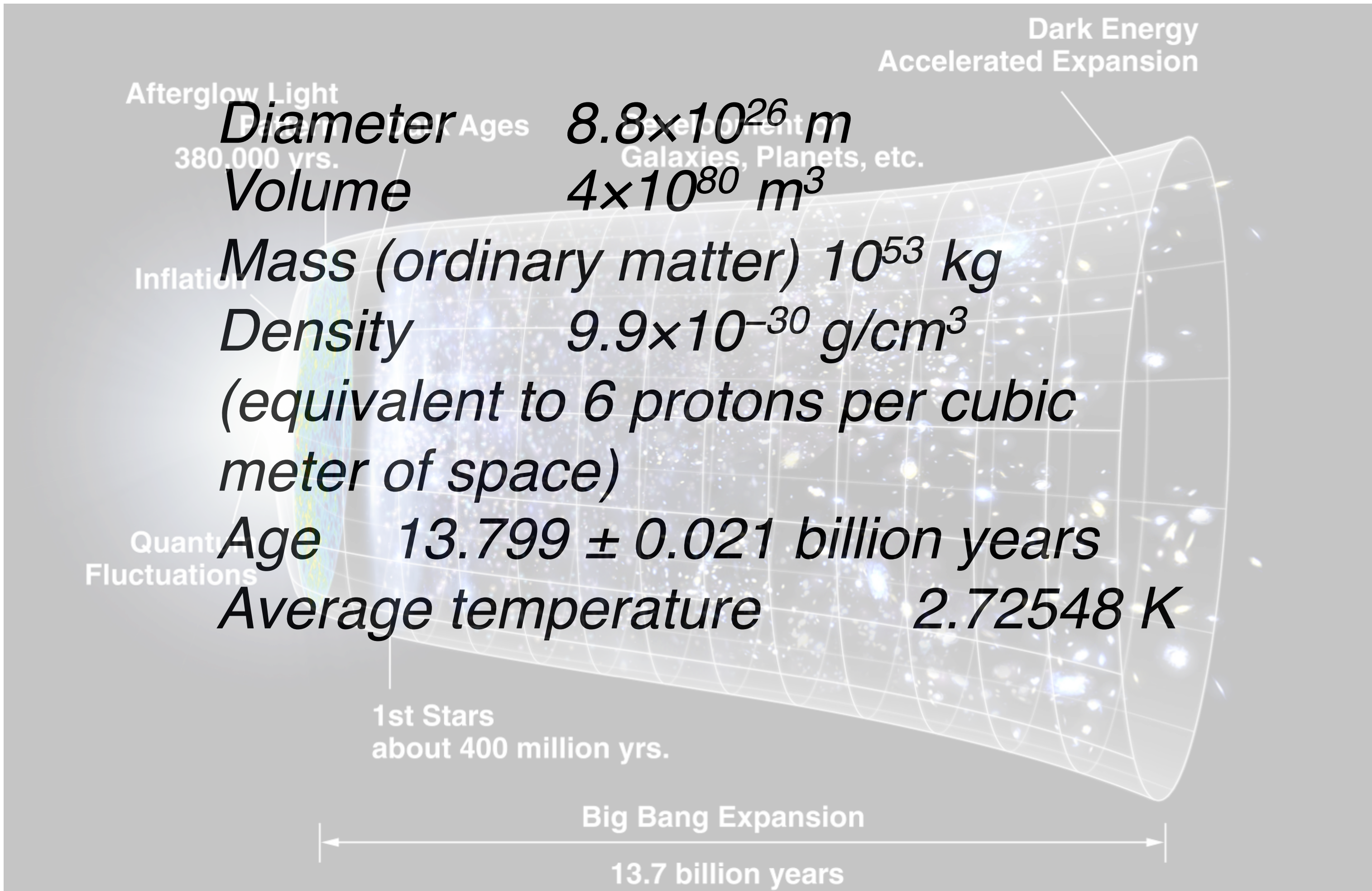
Fig. 1 The multiple components that compose our universe.Dark energy comprises 69% of the mass energy density of the universe, dark matter comprises 25%, and "ordinary" atomic matter makes up 5%.



David N. Spergel Science 2015;347:1100-1102

Published by AAAS

Properties of the Universe



Diameter 8.8×10^{26} *m*

Volume 4×10^{80} *m*^{3}

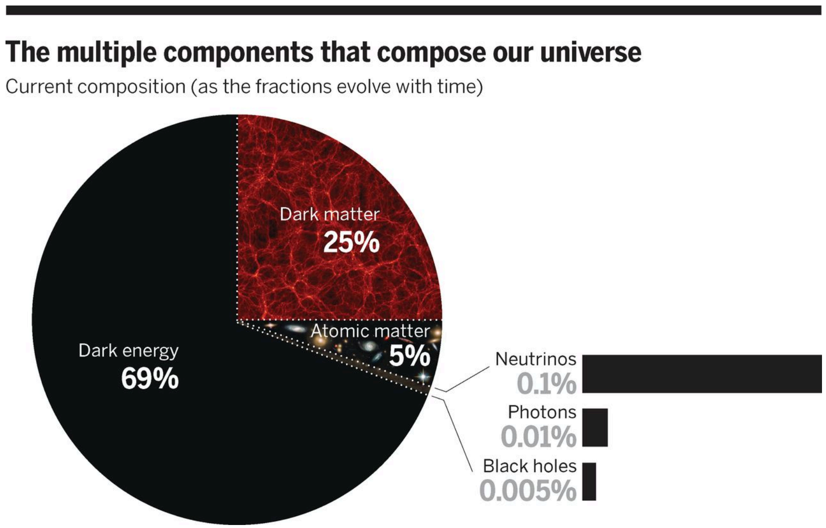
Mass (ordinary matter) 10^{53} *kg*

Density 9.9×10^{-30} *g/cm*^{3} *(equivalent to 6 protons per cubic meter of space)*

Age *13.799 ± 0.021 billion years*

Average temperature *2.72548 K*

QUESTION



The estimated total mass of observable ordinary atomic matter in the universe is 10^{53} kg. Based on this estimate, the amount of dark matter is:

A. 25×10^{53} kg
B. 10^{265} kg
C. 5×10^{53} kg
D. 1×10^{53} kg
E. 30×10^{53} kg

Percent

A comparison based on normalization to 100.

In mathematics, a percentage is a number or ratio expressed as a fraction of 100. It is denoted by the percent sign, %, and is a dimensionless (pure) number.

- *George Washington University:*
- *64 unsealed addressed envelopes with $10 in each were dropped on campus in two different classrooms.*
- *In economics 18 of 32 were mailed back, in [business, history and psychology] 10 of 32 were mailed.* ***(WSJ)***

QUESTION

George Washington University:
64 unsealed addressed envelopes with $10 in each were dropped on campus in two different classrooms.

- *In economics (econ) 18 of 32 were mailed back, in [business, history and psychology (bhp)] 10 of 32 were mailed. What is the percent for each of the 2 groups of students?*

  A. *28% econ 72% bhp*
  B. *56% econ 44% bhp*
  C. *56% econ 31% bhp*
  D. *79% econ 31% bhp*
  E. *79% econ 44% bhp*

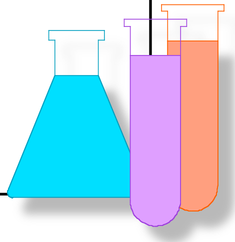
QUESTION

Percent Continued

- 64 unsealed addressed envelopes with $10 in each were dropped on campus in two different classrooms.
- The professor conducting the study received 43.75% of the original $640 in the mail. How much did he receive?

A. $28.00
B. $43.75
C. $140.00
D. $280.00
E. $360.00

(WSJ)



QUESTION
Percent Continued

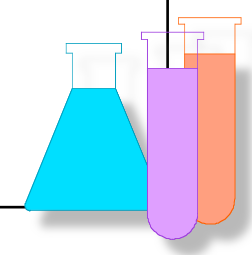
- *Would you mail the envelop presuming no one knows you found it?*
- *One student mailed an empty envelop with the return address:*
- *Mr. IOU, 1013 Indebted Lane, Bankrupt City, MS*

Did the professor count this envelope in the data?

A. YES
B. NO

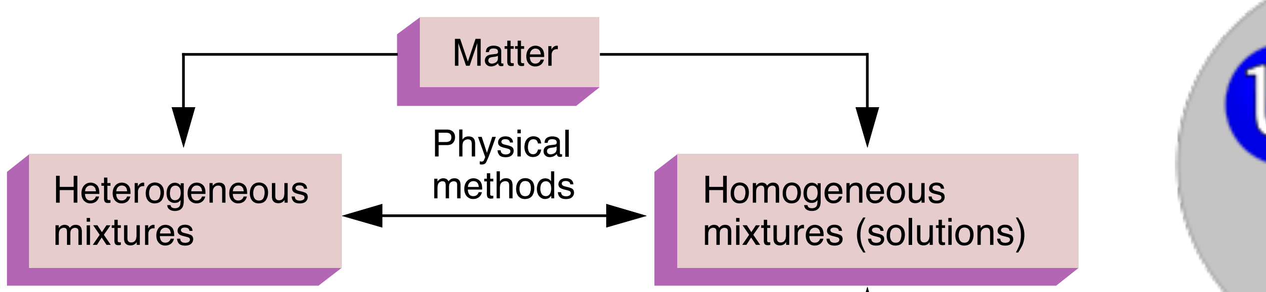
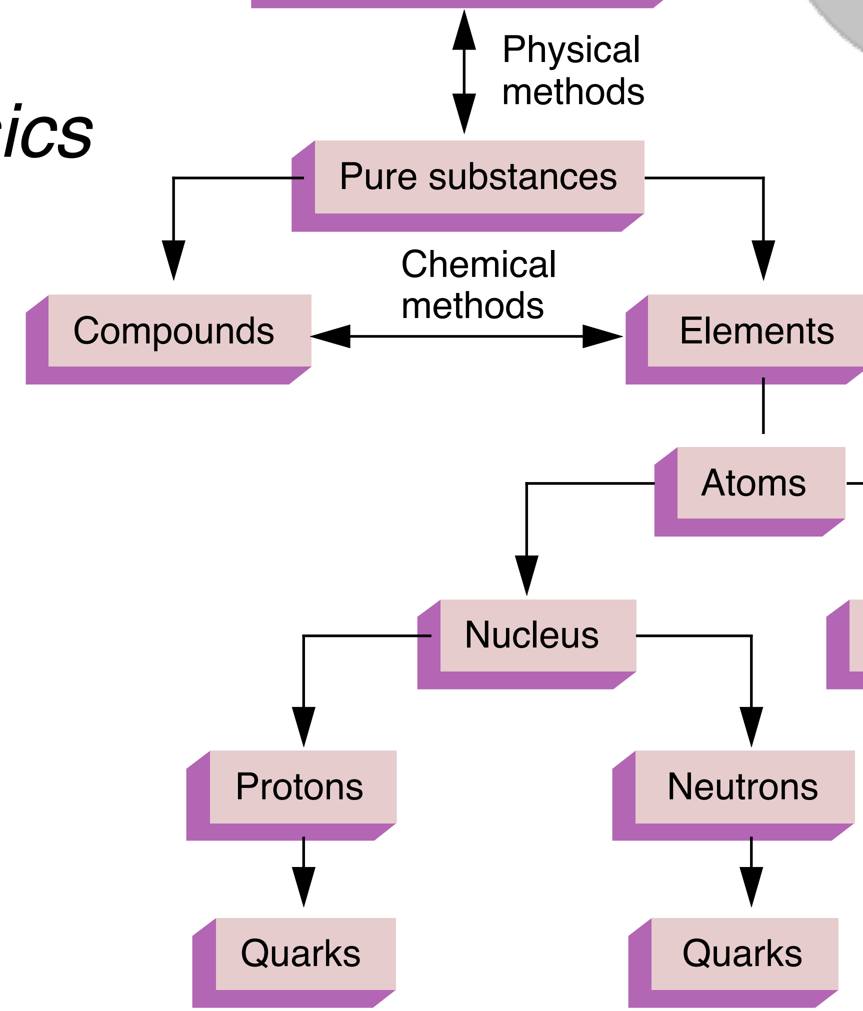
Be prepared to explain your answer.

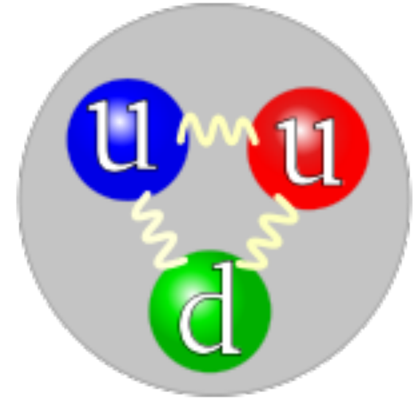
(WSJ)



Chemistry ⇆ Physics

Classification of Matter

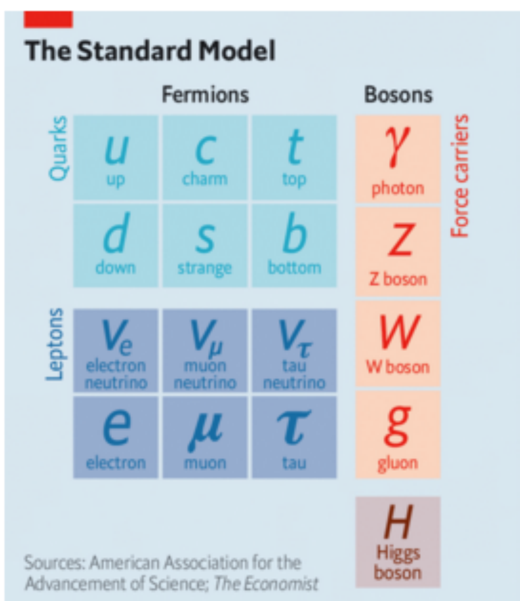


proton

leptons

muon, tau, neutrino

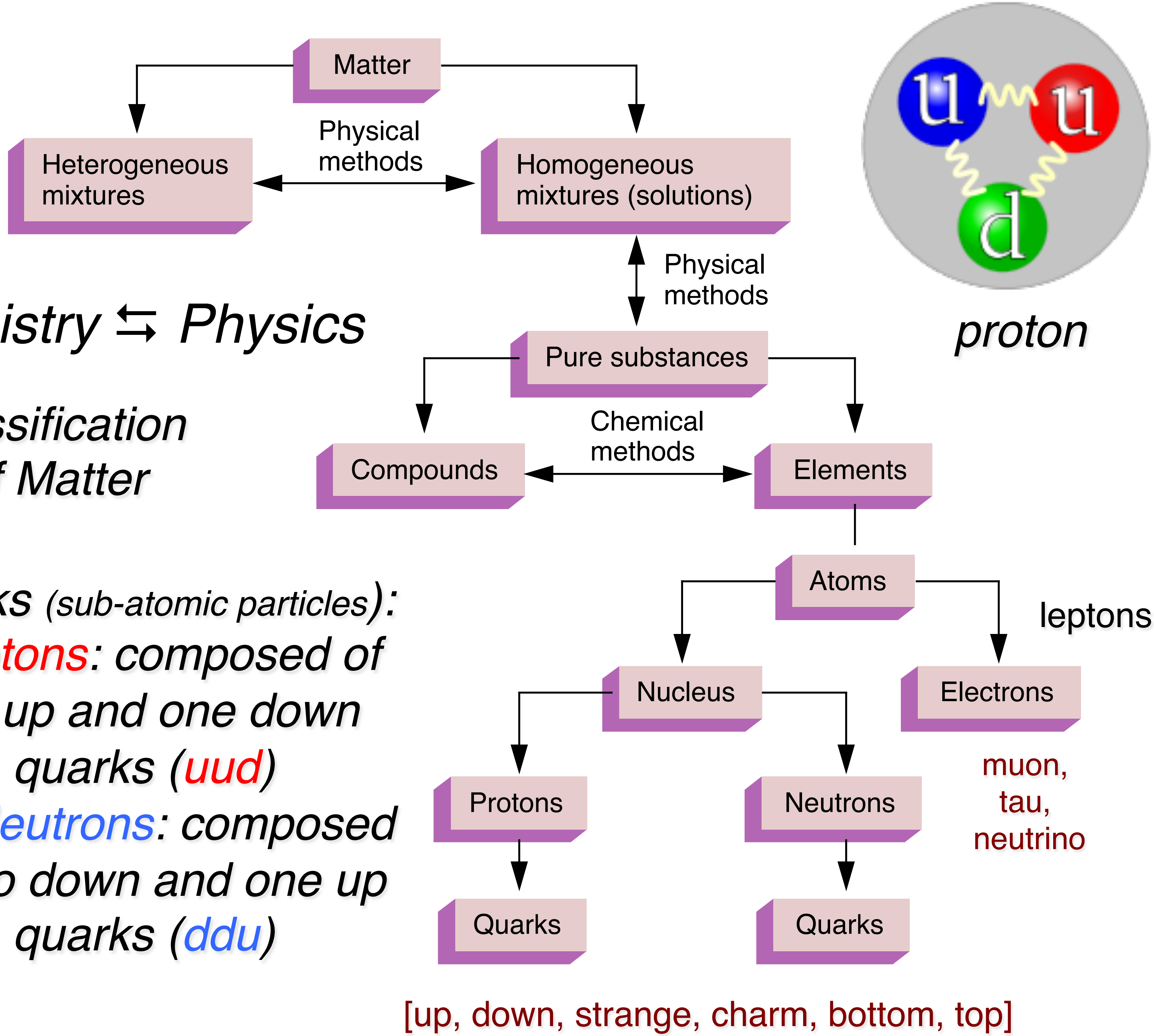
[up, down, strange, charm, bottom, top]



The Economist

Chemistry ⇆ Physics

Classification of Matter



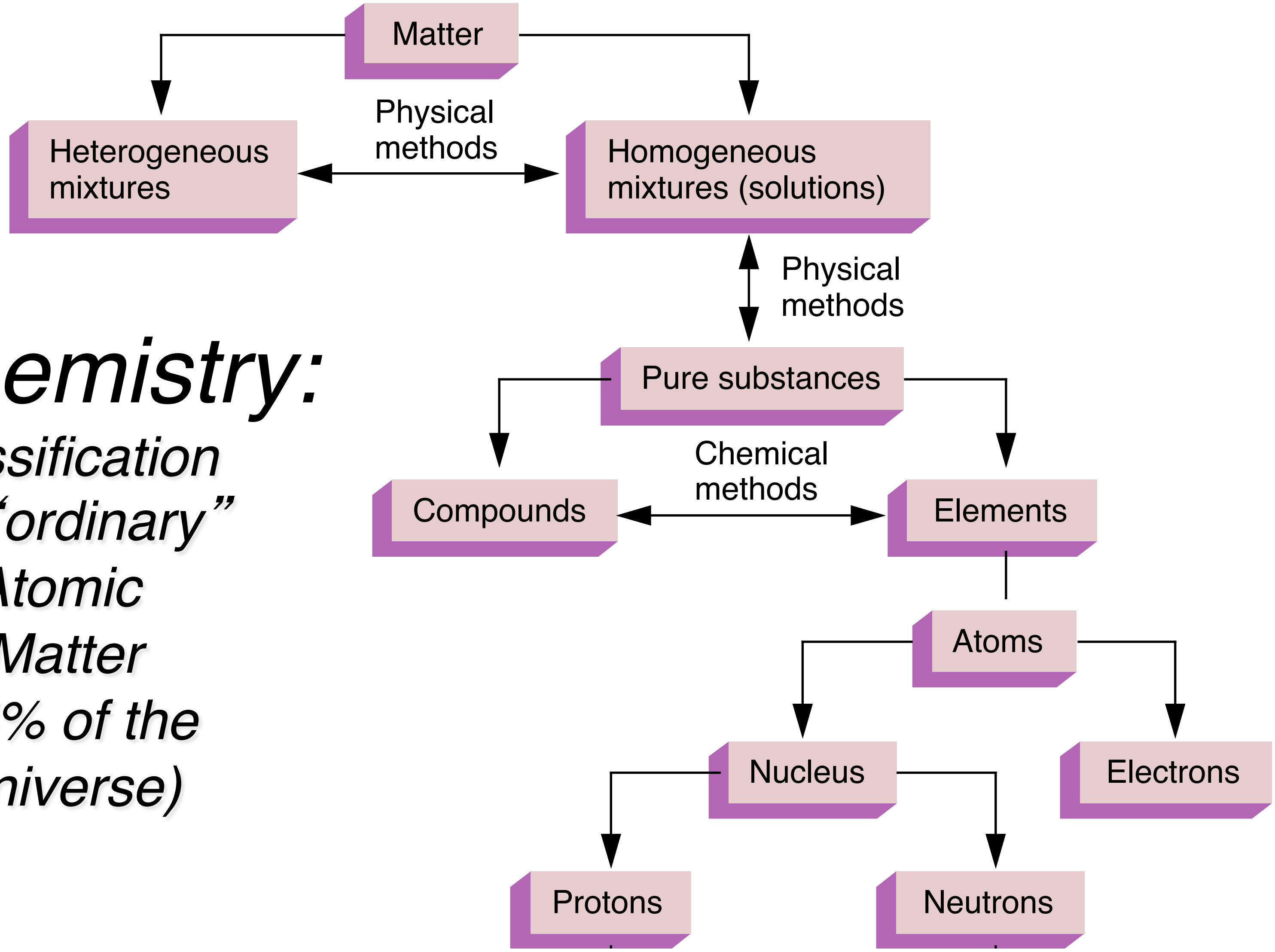
Quarks (sub-atomic particles):

** Protons: composed of two up and one down quarks (uud)*

** Neutrons: composed of two down and one up quarks (ddu)*

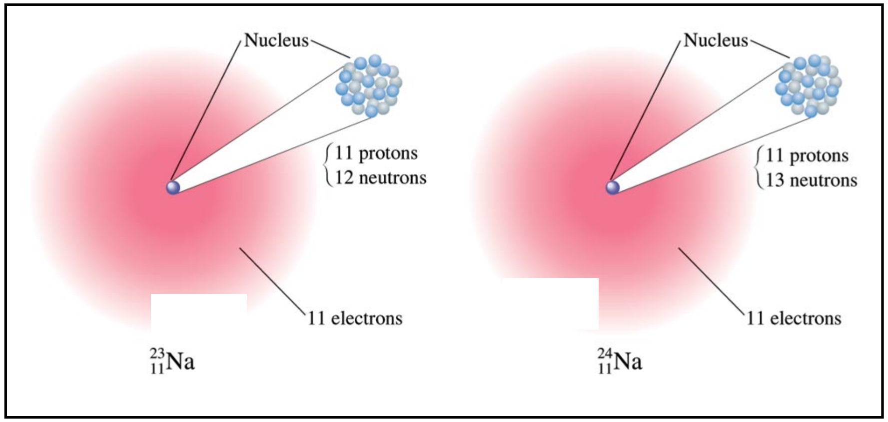
Chemistry:

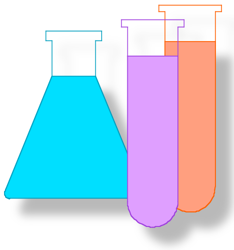
Classification of "ordinary" Atomic Matter (~5% of the Universe)



Atoms (CHEM 108)

- Atoms consist of 3 sub-atomic particles
  - # Protons = Atomic Number = Unique Name
  - # of Neutrons [different numbers = isotopes]
  - # of Electrons [different numbers = ions]





QUESTION

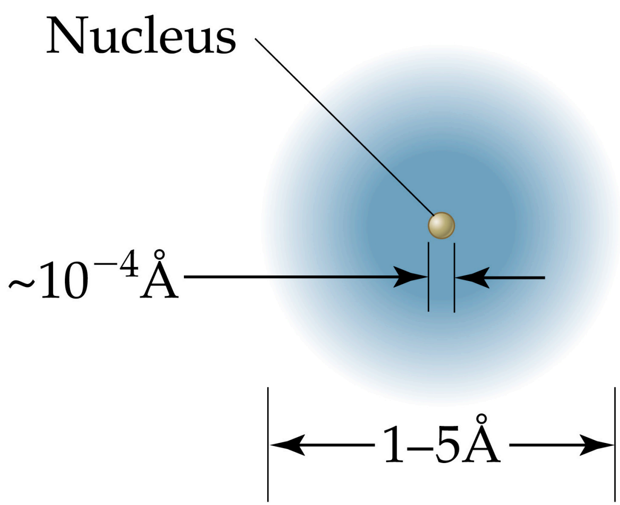
Which statement is incorrect for the three atoms in the following table.

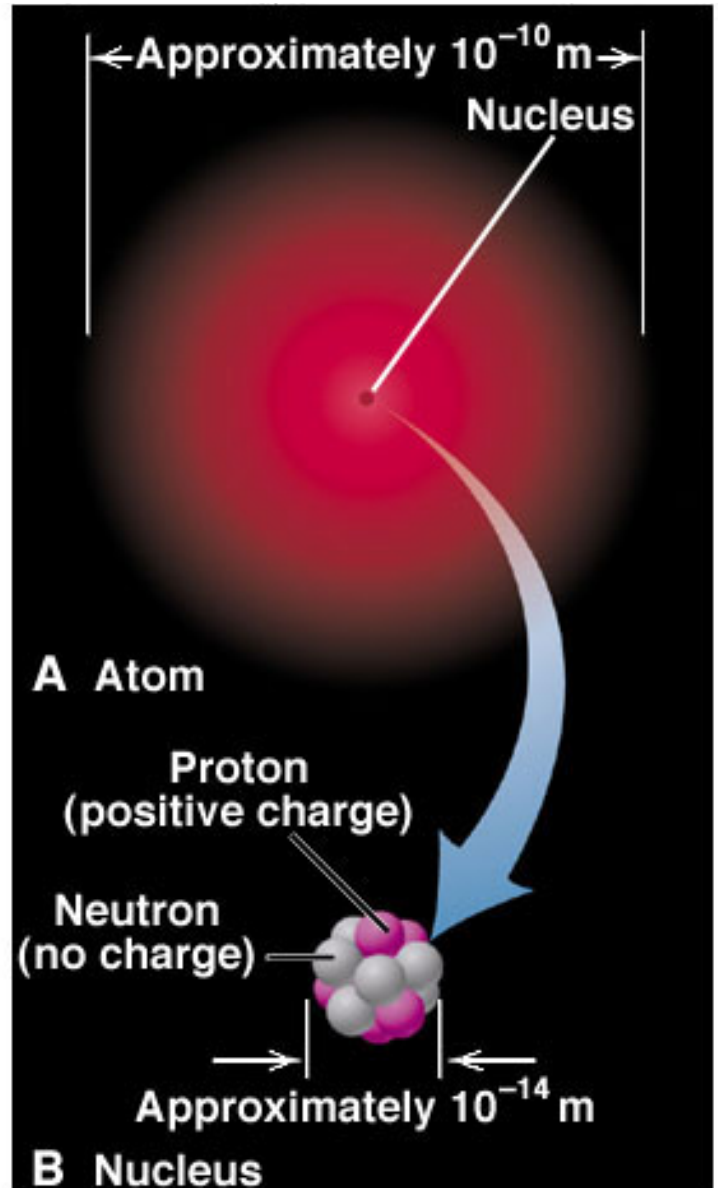
Atom	# protons	# neutrons	# electrons
1	6	6	5
2	6	7	6
3	6	8	7

A. Atoms 1, 2, and 3 have the same name.
B. Atoms 1, 2, and 3 are isotopes.
C. Atoms 1, 2, and 3 are ions.
D. Atoms 1, 2, and 3 are not identical.

General Features of the Atom

Anders Jöns Ångström
(1814-1874)
1 Å = 10 picometers = 0.1 nanometers = 10^{-4} microns = 10^{-8} centimeters





~ 0.1 nm

Nucleus = 1/10,000 of the atom

- *1 nm = 10 Å*
- *An atom vs. a nucleus*

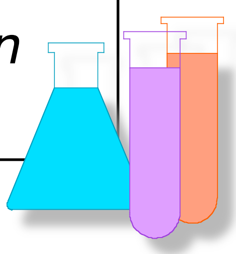
~10,000 x larger

CHEMISTRY of the Atom

FUNDAMENTAL PARTICLES:

	Mass	Charge	Symbol
Nucleus:			
• *PROTON*	*1 amu*	*+1*	*H+, H, p*
	• *1.67 x 10 $^{-27}$ kg*		
• *NEUTRON*	*1 amu*	*0*	*n*
	• *1.67 x 10 $^{-27}$ kg*		
• *ELECTRON*	*very small*	*-1*	*e^-*
	• *≈ 2000 x smaller than a proton or neutron*		

The particle is said to "hold" or "bond" atoms together in molecules.



QUESTION

Which statement is correct for the three atoms in the following table.

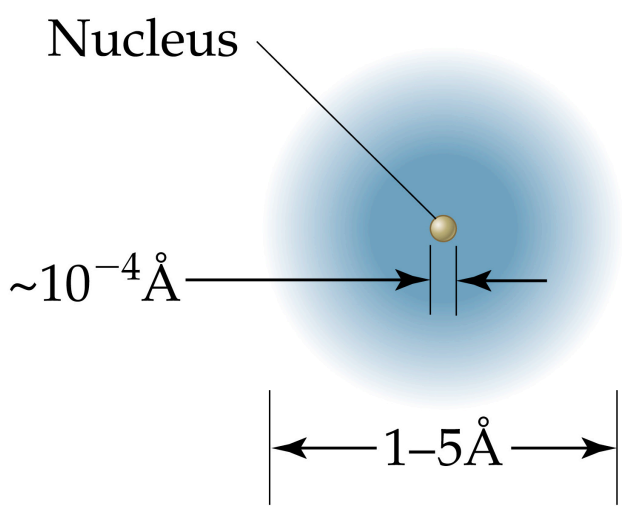
Atom	# protons	# neutrons	# electrons
1	6	6	5
2	6	7	6
3	6	8	7

A. Atoms 1, 2, and 3 have the same mass.
B. Atoms 1, 2, and 3 have the same charge.
C. Atoms 1 and 3 have the same charge.
D. Atoms 1, and 3 have the same mass.
E. Atoms 1, 2, and 3 have different masses and different net charges.

http://science.kqed.org/quest/video/the-worlds-most-powerful-microscope/

Can we "see" individual atoms using a microscope?

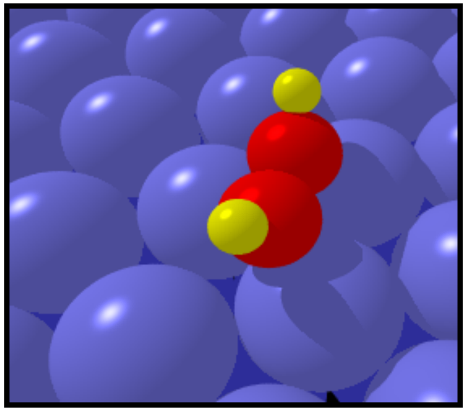
With TECHNOLOGY: Yes, using atomic force microscopy (AFM) and a variety of instruments such as Scanning Transmission Electron Microscopes.

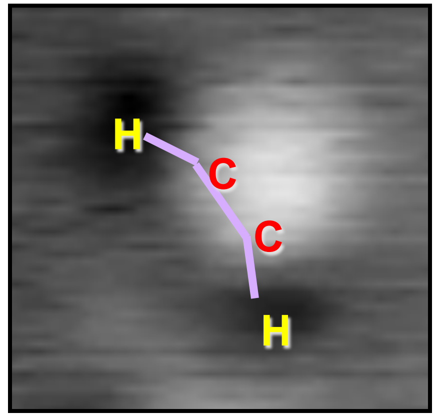


- *1 nm = 10 Å*
- *An atom vs. a nucleus ~10,000 x larger*

TEAM 0.5:
LBL's
***T**ransmission*
***E**lectron*
***A**berration-corrected*
***M**icroscope*
Resolution:
+/- 0.5 Å (0.05 nm)

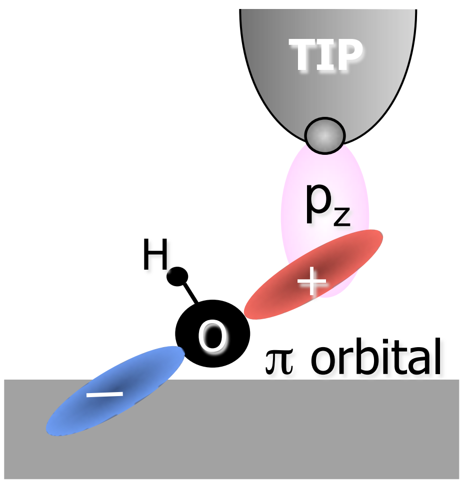
Imaging: acetylene on Pd(111) at 28 K

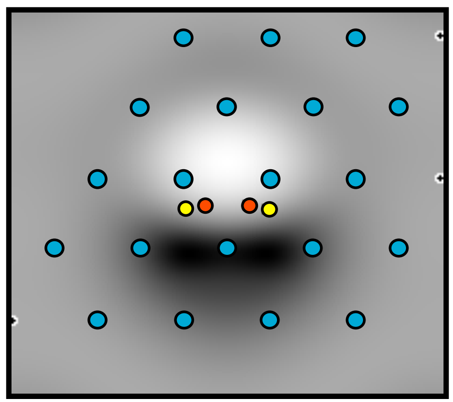




Molecular Image
Tip cruising altitude ~700 pm
Δz = 20 pm

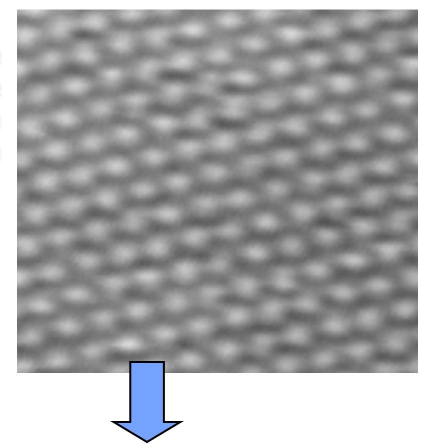
We don't see the Pd atoms because the tip needs to be very close to image the Pd atoms and would knock the molecule away





Calculated image
(Philippe Sautet)

Surface atomic profile
Tip cruising altitude
~500 pm
Δz = 2 pm



If the tip was made as big as an airplane, it would be flying at 1 cm from the surface and waving up an down by 1 micrometer

The STM image is a map of the pi-orbital of distorted acetylene

M. Salmeron (LBL)