

# Chem 108

## Introductory Chemistry

Dr. Ron Rusay

**CONNECTIONS: Chemistry  $\Leftrightarrow$  STE(A)M**

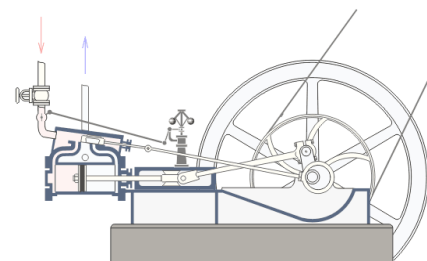
**STE(A)M**

**S Science**

**T Technology**

**E Engineering**

**M Mathematics**



**< A: Arts & Applications**



# *Chemistry Connections*

## *(CHEM 108)*

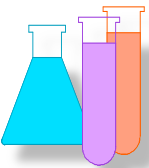
- *STE(A)M ↔ Chemistry ↔ Allied Careers*
  - *Linked by the Scientific Method*

*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,*

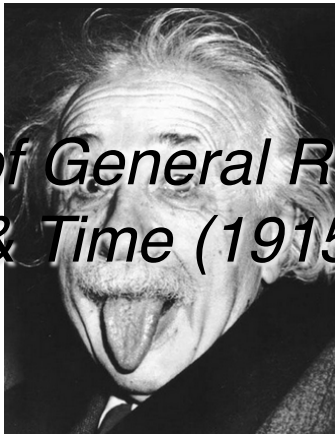
*New Materials: Structural, Mechanical, Industrial & Molecular*



# *Law or Theory of Gravity?*

*Hipparchus and Erasthones (~ 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 property of space-time geometry.*

*[https://www.youtube.com/watch?  
v=wtsNOMTIS7E](https://www.youtube.com/watch?v=wtsNOMTIS7E)*

*Which falls faster, a feather or a hammer?  
..... in a vacuum? ..... on the moon?*



# Chemistry $\Leftrightarrow$ Physics

## The Scientific Method (A Unifying Practice)

**Do objects made of different materials with different masses accelerate at the same speed when dropped? (Equivalence Principle)**

**Three ways to test the equivalence principle**

To test whether inertial and gravitational masses are the same, scientists can check whether objects made of different materials fall at different rates, orbit at different distances above Earth, or curve a beam on a torsion oscillator. The test would come about if the net force produced by gravity's pull is balanced by the vector of Earth and the centrifugal force produced by Earth's rotation period (a different condition for each weight).

Adrian Cho Science 2015.347:1096-1099

Science

**GENERAL RELATIVITY**

A superbook, superainless guide to the theory that conquered the universe.

<http://spark.sciencemag.org/generalrelativity?int-cmp=print-comic>

THE SOLUTION: GRAVITY IS **WARPED**

Click here for on-line

The comic book  
Adrian Cho, *Science*, 6 March 2015:  
1094-1095.  
A superbook, superainless  
guide to the theory that  
conquered the universe.  
Click here for pdf

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

The comic book  
Adrian Cho, *Science*, 6 March 2015:  
1094-1095.  
A superbook, superainless guide to the theory that conquered the universe.

<http://www.einstein-online.info/spotlights>  
<http://einsteinpapers.press.princeton.edu/vol6-d00292>

35. "The Field Equations of Gravitation"

<https://www.youtube.com/watch?v=6RPKAKZw8>

$$d^2 = -c^2 dt^2 + R(t)^2 \left( \frac{dr^2}{1 - kr^2} + r^2 d\theta^2 + r^2 \sin^2 \theta d\phi^2 \right)$$

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

The comic book  
Adrian Cho, *Science*, 6 March 2015:  
1094-1095.  
A superbook, superainless guide to the theory that conquered the universe.

**LOOK HERE**

(It is a clear visual explanation of Einstein's theory.)

**But is there a LAW of Gravity?**

A Scientist Takes On Gravity

New York Times, July 12, 2010

[http://www.nytimes.com/2010/07/13/science/13gravity.html?\\_r=1&ref=space](http://www.nytimes.com/2010/07/13/science/13gravity.html?_r=1&ref=space)

**The LAW or THEORY of Gravity?**

High Energy Physics - Theory

**On the Origin of Gravity and the Laws of Newton**

Erik P. Verlinde  
Submitted on 6 Jan 2010

Starting from first principles and general assumptions Newton's law of gravitation is shown to arise naturally and unavoidably in a theory in which space is emergent through a holographic scenario. Gravity is explained as an entropic force caused by changes in the information associated with the positions of material bodies. A relativistic generalization of the presented arguments directly leads to the Einstein equations. When asked if emergent even Newton's law of inertia needs to be explained, the equivalence principle leads us to conclude that it is actually this law of inertia whose origin is entropic.

Comments: 23 pages, 6 figures.  
Subjects: High Energy Physics - Theory (hep-th)  
Cite as: arXiv:1001.0785v1 [hep-th]

<http://arxiv.org/abs/1001.0785>

# Chemistry $\leftrightarrow$ Physics

## Law vs. Theory

[A New Explanation of Gravity](#)

<http://www.youtube.com/watch?v=vyomGtZCsmI>

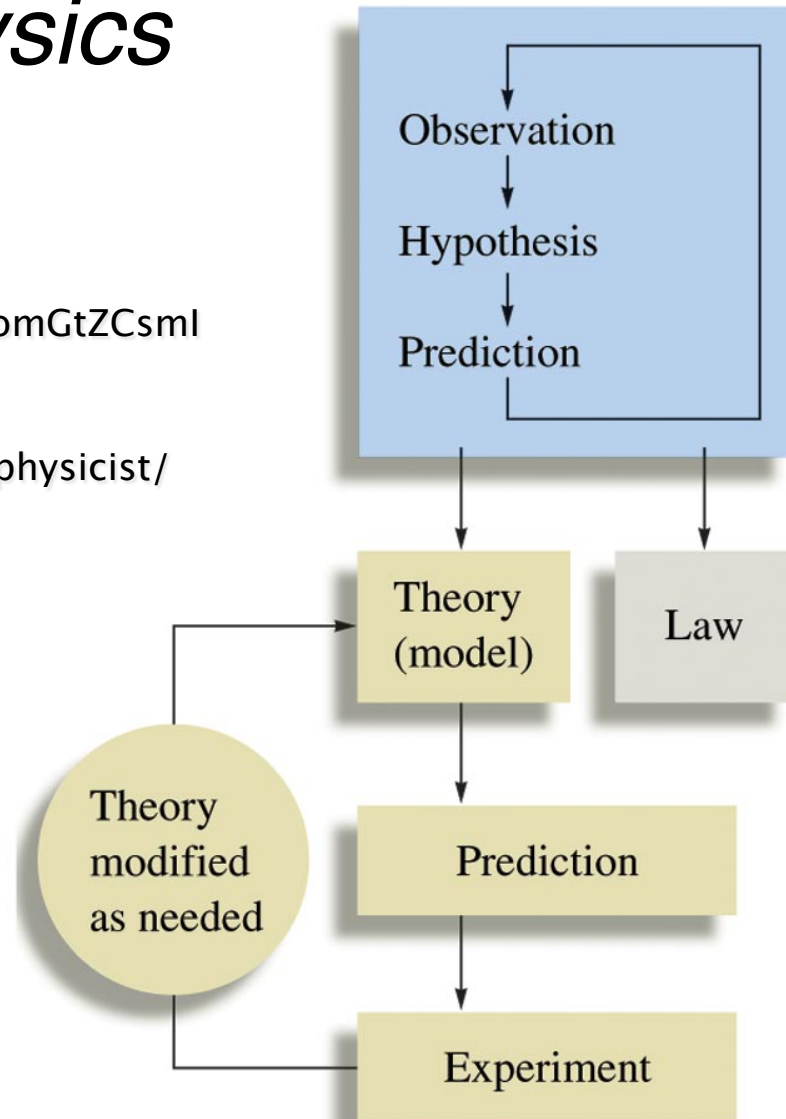
[The Case of Gravity](#)

[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<sup>6</sup>*

*“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***

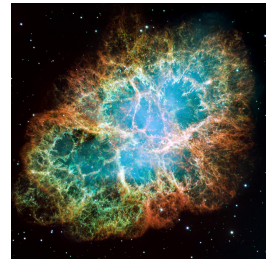
*Which statement most resembles a scientific theory?*

- 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.<sup>[1][2]</sup> 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.<sup>[3]</sup>*

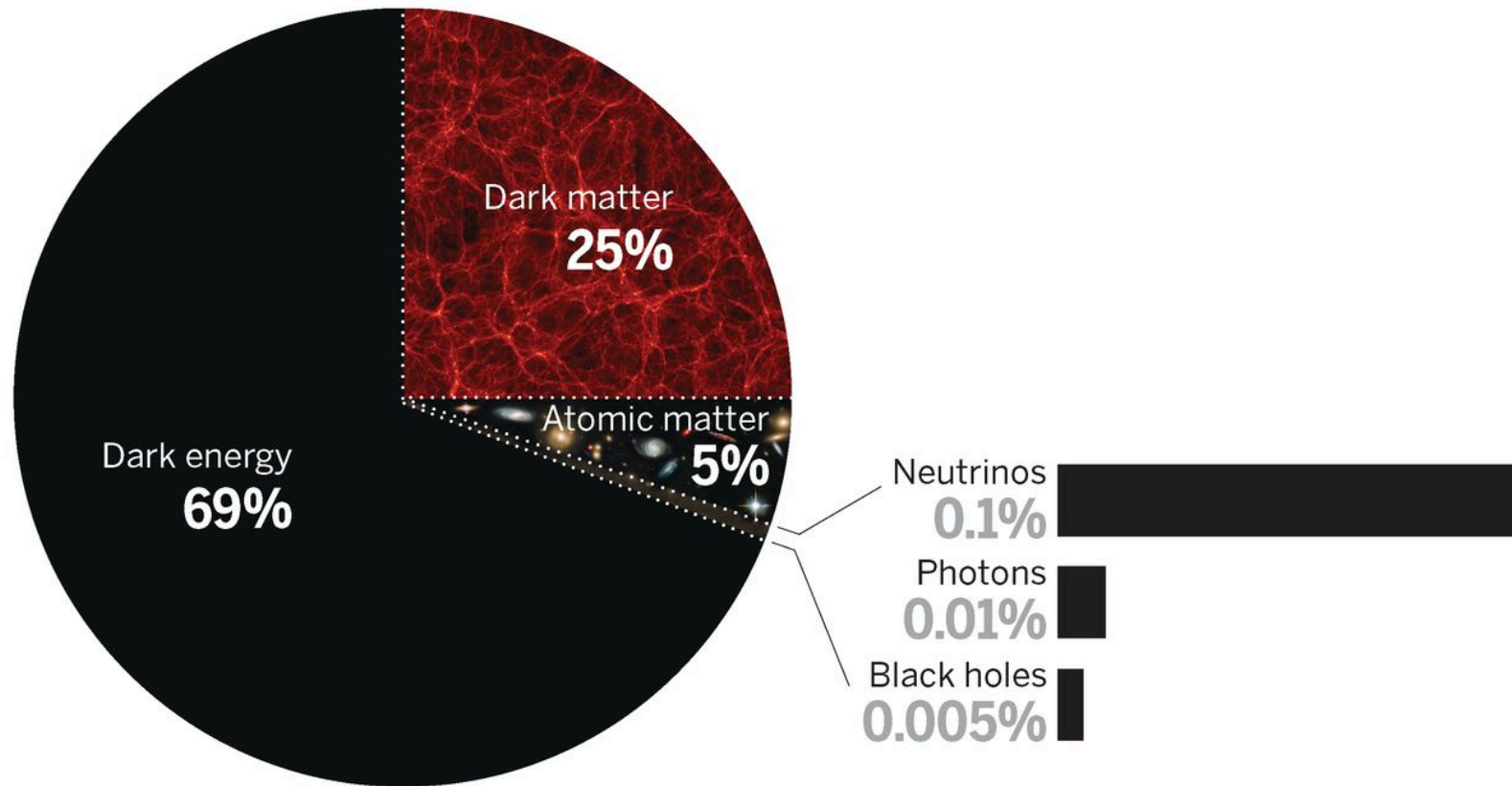
*Dark matter is matter that is undetectable by emitted or absorbed radiation, but whose presence can be inferred from gravitational effects.*

- 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%.**

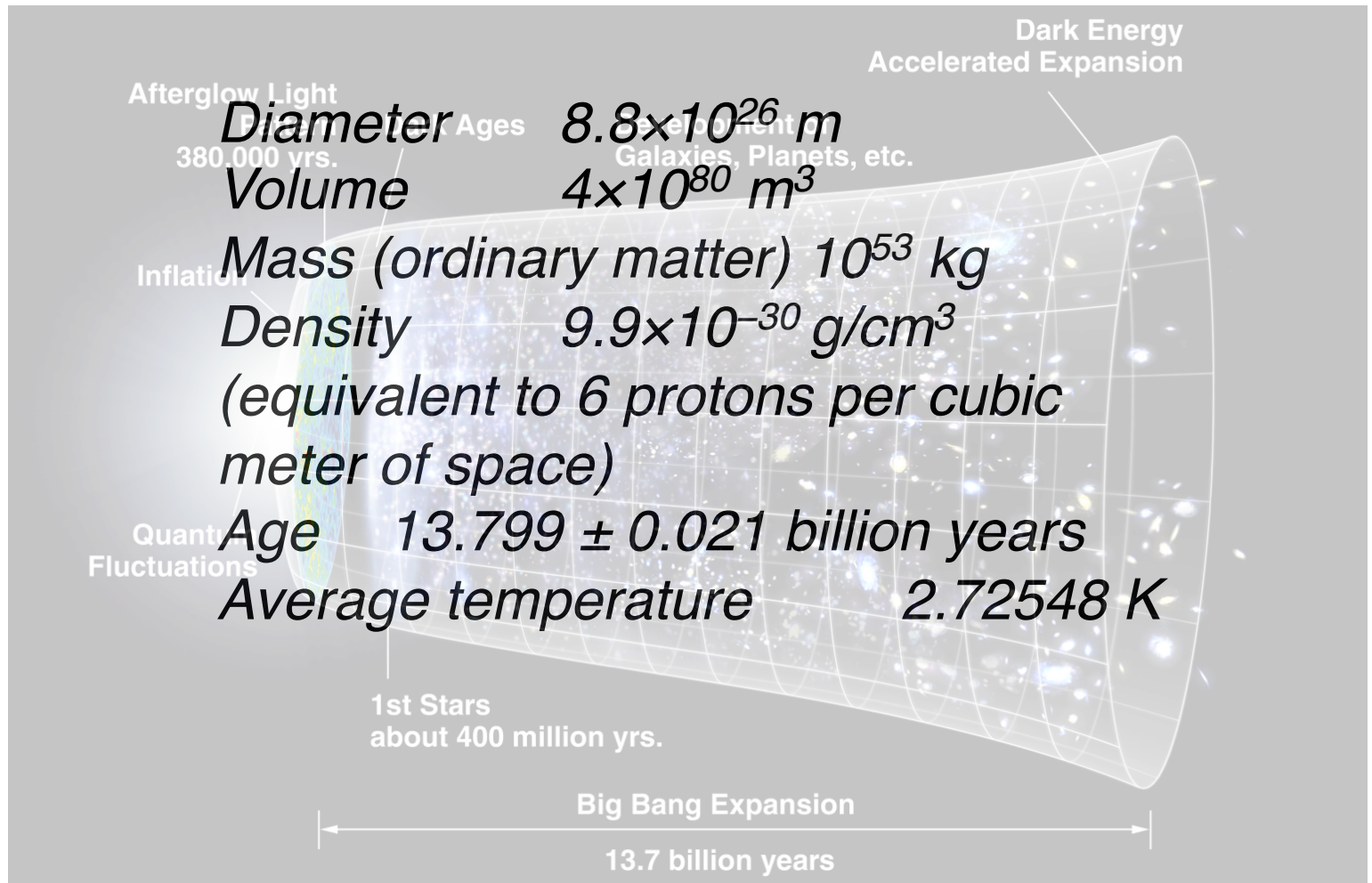
## The multiple components that compose our universe

Current composition (as the fractions evolve with time)



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

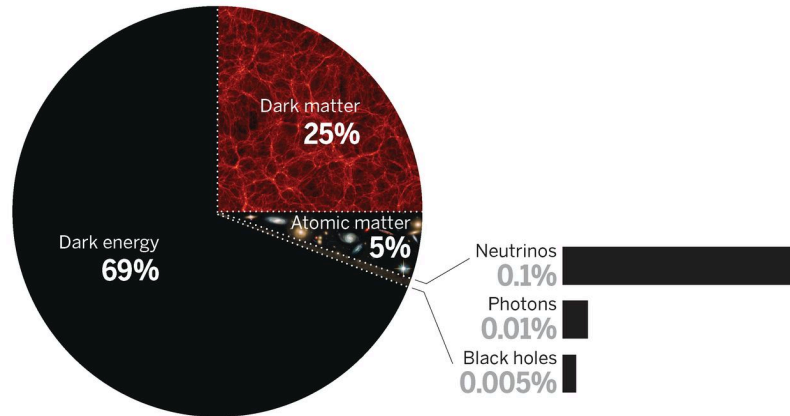
# Properties of the Universe



# QUESTION

## The multiple components that compose our universe

Current composition (as the fractions evolve with time)



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.  $25 \times 10^{53}$  kg
- B.  $10^{265}$  kg
- C.  $5 \times 10^{53}$  kg
- D.  $1 \times 10^{53}$  kg
- E.  $30 \times 10^{53}$  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***

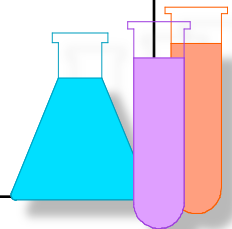
# QUESTION

*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*

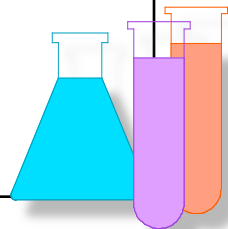
*Did the professor count this envelope in the data?*

A. YES

B. NO

*Be prepared to explain your answer.*

**(WSJ)**



# *Answer*

## *Percent Continued*

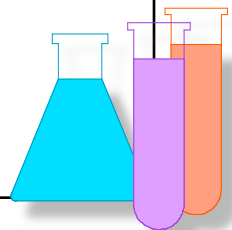
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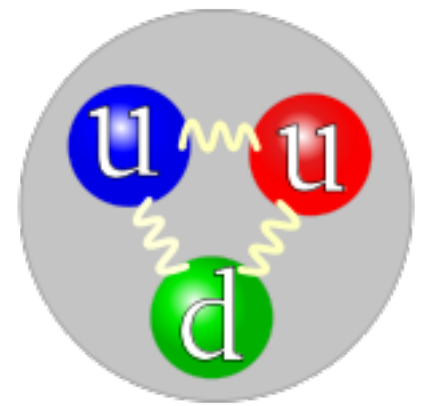
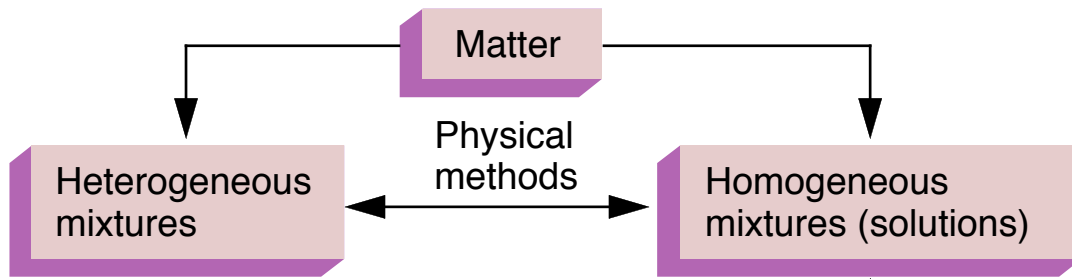
*Did the professor count this envelope in the data?*

*A. YES*

*B. NO*

*\$280 mailed back:  $\$280 / \$10 = 28$  students*  
*“28 students” / 64 students  $\times 100 = 43.75\%$*

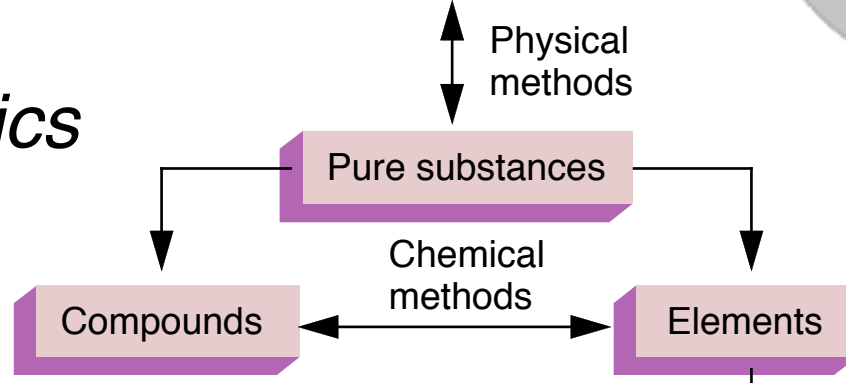




*proton*

*Chemistry ↔ Physics*

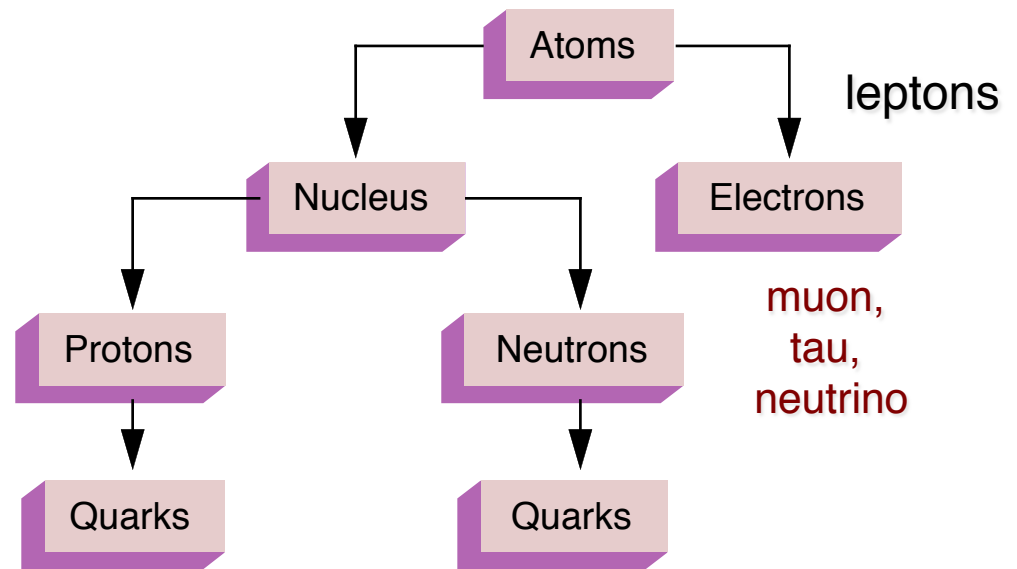
*Classification of Matter*



*Quarks (sub-atomic particles):*

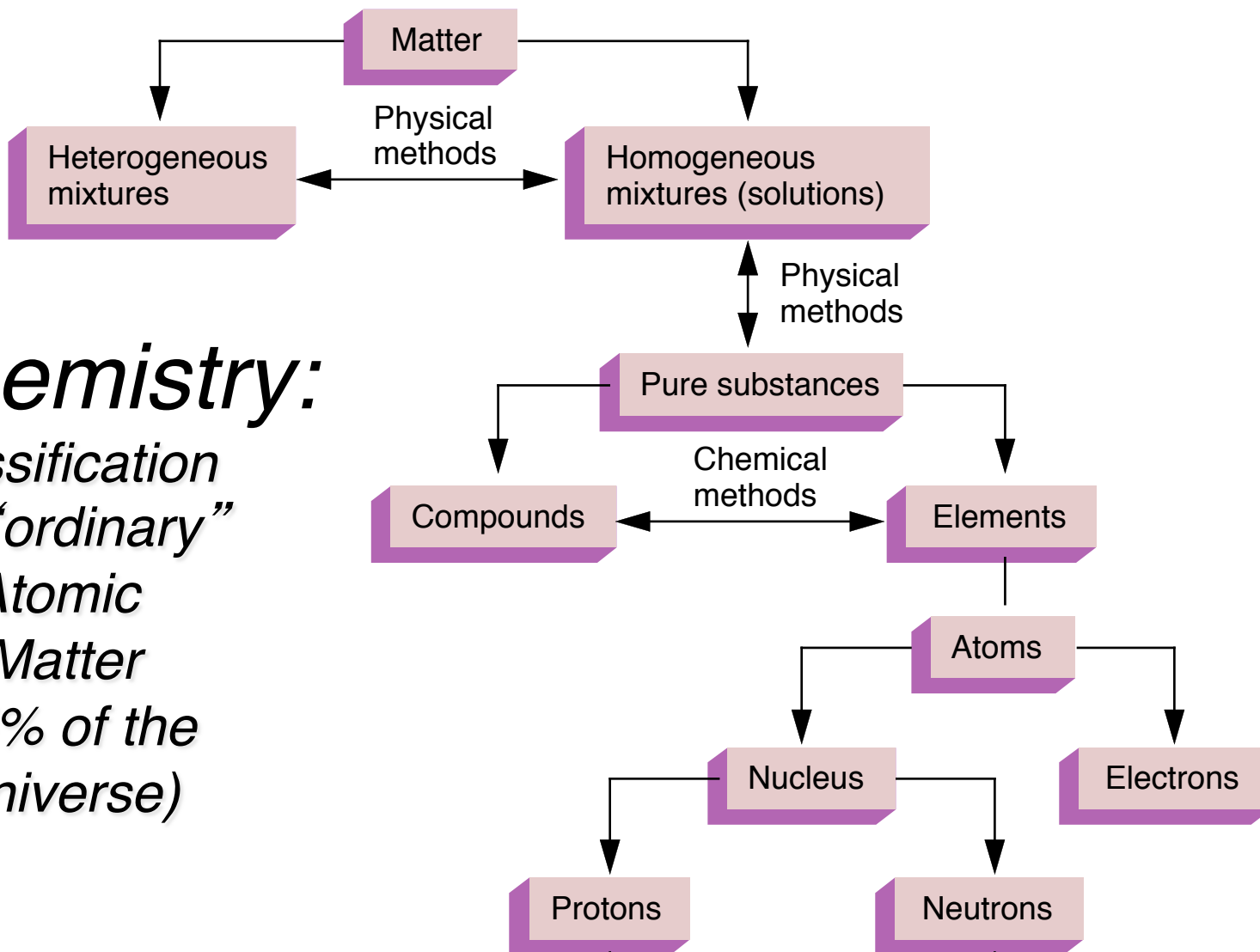
\* **Protons**: composed of two up and one down quarks (*uud*)

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



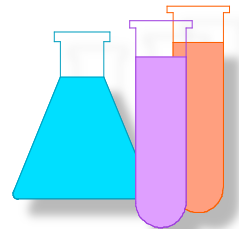
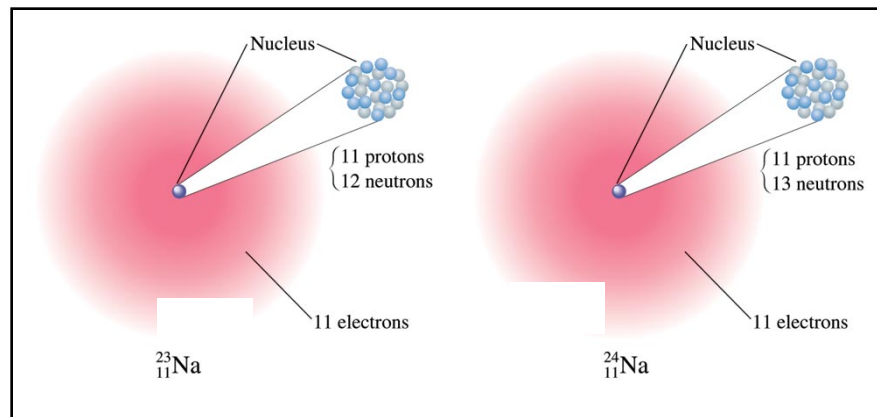
[up, down, strange, charm, bottom, top]

***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.*

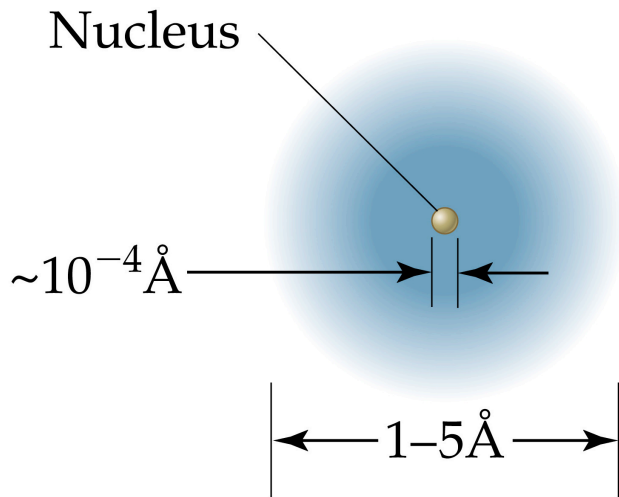
Atom	# protons	# neutrons	# electrons
1	6	6	5
2	6	7	6
3	6	8	7

- 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.*

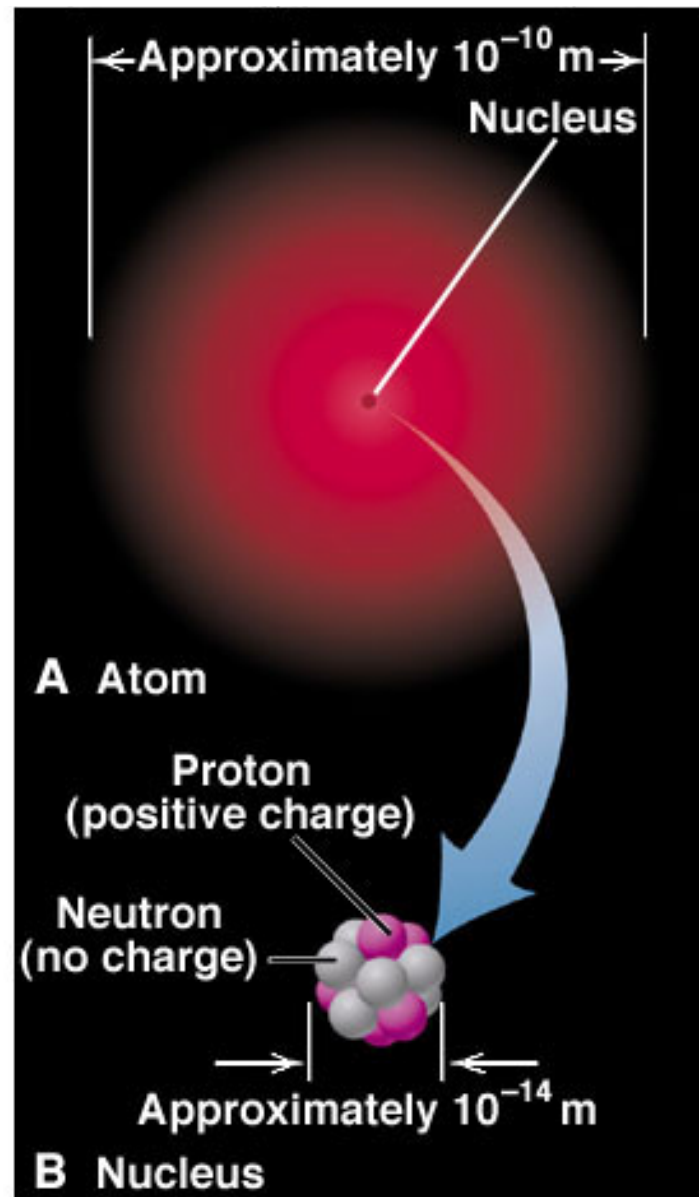
# General Features of the Atom

Anders Jöns Ångström  
(1814-1874)

1 Å = 10 picometers = 0.1 nanometers =  
10<sup>-4</sup> microns = 10<sup>-8</sup> centimeters



- $1 \text{ nm} = 10 \text{ \AA}$
- *An atom vs. a nucleus  
~10,000 x larger*



~ 0.1 nm

*Nucleus =  
1/10,000  
of the atom*

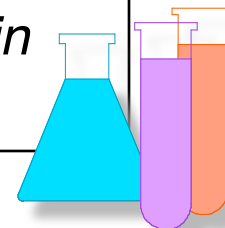
# CHEMISTRY of the Atom

## FUNDAMENTAL PARTICLES:

	<u>Mass</u>	<u>Charge</u>	<u>Symbol</u>
<i>Nucleus:</i>			
• <b>PROTON</b>	1 amu • $1.67 \times 10^{-27}$ kg	+1	H+, H, p
• <b>NEUTRON</b>	1 amu • $1.67 \times 10^{-27}$ kg	0	n

- 
- **ELECTRON** very small -1  $e^-$ 
    - $\approx 2000$  x smaller than a proton or neutron

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



# QUESTION

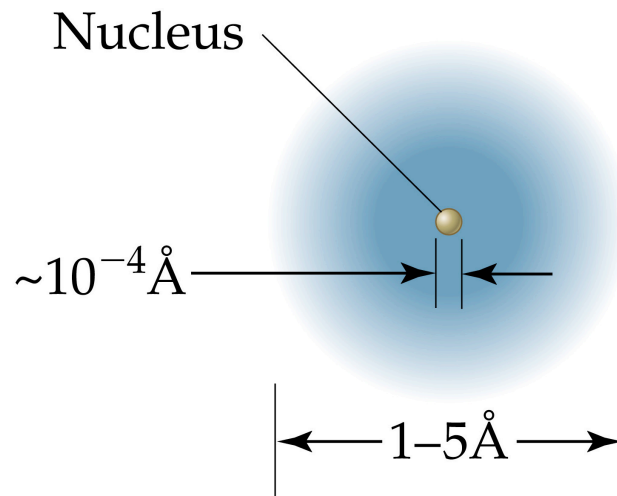
*Which statement is correct for the three atoms in the following table.*

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.*

Can we “see” individual atoms using a microscope?

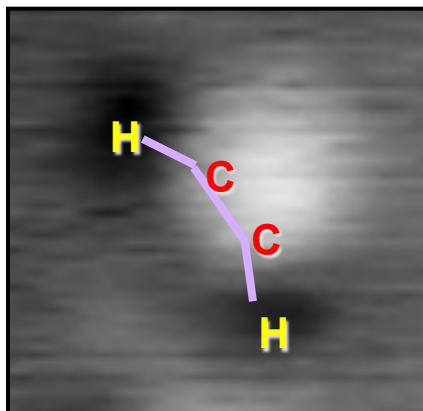
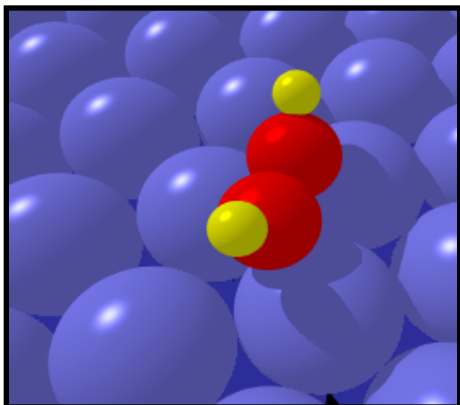
*With TECHNOLOGY: Yes, using atomic force microscopy (AFM) and a variety of instruments such as Scanning Transmission Electron Microscopes.*



- $1 \text{ nm} = 10 \text{ \AA}$
- An atom vs. a nucleus  
 $\sim 10,000 \times$  larger

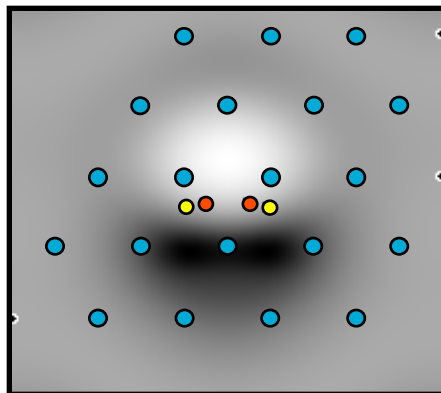
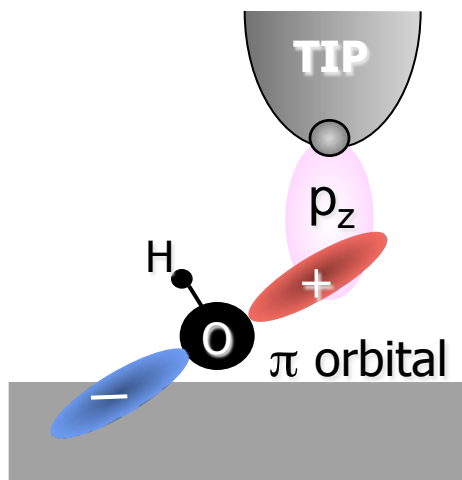
**TEAM 0.5:**  
LBL's  
Transmission  
Electron  
Aberration-corrected  
Microscope  
Resolution:  
 $\pm 0.5 \text{ \AA}$  (0.05 nm)

# Imaging: acetylene on Pd(111) at 28 K



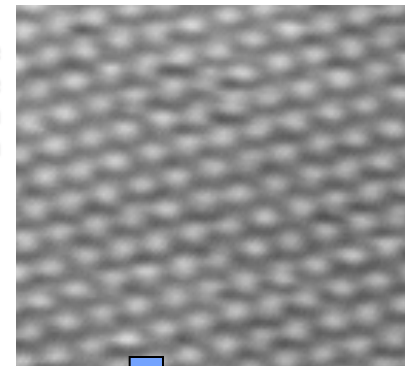
**Molecular Image**  
Tip cruising altitude  $\sim 700 \text{ \AA}$   
 $\Delta z = 20 \text{ \AA}$

*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  
 $\sim 500 \text{ \AA}$   
 $\Delta z = 2 \text{ \AA}$



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



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

*M. Salmeron (LBL)*