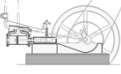


Chem 108 Introductory Chemistry

Dr. Ron Rusay

CONNECTIONS: Chemistry \rightleftharpoons STEM \rightleftharpoons Applications

STEM
S Science
T Technology
E Engineering
M Mathematics



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Chemistry Connections (CHEM 108)


- **STEM \rightleftharpoons Chemistry \rightleftharpoons Allied Careers**
- **Linked by the Scientific Method**

Chemistry focuses on the study of

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

All Science, Technology & Engineering involves:

- **Observations & Measurements:**
(Qualitative & Quantitative using international [SI] & related metric units)



Chemistry Connections (CHEM 108)


Mathematics is the collection of tools used to analyze observations, test results and predict outcomes. It has many, many forms but can be broken down into two general areas:

Calculations & Modeling, which depend on the problem and questions to be answered

Academic Math Skills that are required in STEM majors vary depending on the subject major:

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

CHEM 108 only requires the ability to accurately add, subtract, multiply, divide, and compare values.




Chemistry \rightleftharpoons Physics \rightleftharpoons 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 \rightleftharpoons Algebra \rightleftharpoons Calculus \rightleftharpoons Differential Equations \rightleftharpoons Partial Differential Equations \rightleftharpoons Linear Algebra \rightleftharpoons Non-linear Equations \rightleftharpoons Non-deterministic Systems

RESULTS: Protocols, Explanations, Predictions & Products
Examples: GPS, Cosmology, Space Travel, Space Probes, New Materials: Structural, Mechanical, Industrial & Molecular




https://www.youtube.com/watch?v=V3XV_GdV0M3pace [5min]




<https://www.youtube.com/watch?v=0iTiKOy59o4>



<https://www.youtube.com/watch?v=7CuYx9mZCQA>

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=wt5NOMTIS7E>

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



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 mass are the same, scientists can check whether objects made of different materials fall at different rates, orbit at different distances above Earth, or cause a twist in a torsional oscillator. The twist would come about if the net force produced by gravity's pull toward the center of Earth and the centrifugal force produced by Earth's rotation pointed in a different direction for each weight.

Adrian Cho *Science* 2015;347:1096-1099

Science
AAAS

Published by AAAS

GENERAL RELATIVITY

A super-quick, super-painless 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 superquick, superpainless 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 superquick, superpainless guide to the theory that conquered the universe.

<http://www.einstein-online.info/spotlights/gr>
<http://einsteinpapers.press.princeton.edu/vol6-doc/262>

25. "The Field Equations of Gravitation"
(Einstein 1915)

Skizzen vom 23. November 1915
Protokoll vom 2. Dezember 1915
Dr. Königlich Preussische Akademie der Wissenschaften (Berlin), Sitzungsberichte (1915), 444-487.

<https://www.youtube.com/watch?v=ioRPFKAKZWx8>

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

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

The comic book
Adrian Cho, *Science*, 6 March 2015:
1094-1095.
A superquick, superpainless 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

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 space is 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: 29 pages, 6 figures
Subjects: High Energy Physics - Theory (hep-th)
Cite as: arXiv:1001.0785v1 [hep-th]

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

Chemistry ⇌ Physics

Law vs. Theory

A New Explanation of Gravity
<http://www.youtube.com/watch?v=vyomGzZCsmI>

The Case of Gravity
http://www.science20.com/hammock_physicist/it_bit_case_gravity

Law(s)? vs. Theory
Spinoza Prize €2.5 x 10⁶
"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.

Applying the Scientific Method

Why have sprinters not reached a plateau?

1. **Observations: See Data**

2. **Formulate a hypothesis:**

- a possible explanation for the observations

3. **Outline a possible experiment**

- to gather new information
- to test whether your hypothesis is valid

Sources: "Limits to running speed in dogs, horses and humans", by M. Beery, *The Journal of Experimental Biology*, 2008: JAAF
 "Citius, altius, fortius, numerus"
Economist, July 18th 2015

Some Possible Steps in the Scientific Method

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

Chemistry (CHEM 108)

The Study of Energy & Matter

- In all forms & all behaviors Can all matter and energy be observed directly?
- Sub-categories (not so distinct any longer)

Organic: carbon
 Inorganic: non-carbon
 Organometallic: organic + inorganic
 Analytical: what?, how much?, how pure?
 Chemical Biology: living organisms
 Physical: energy, changes, rates
 Nuclear: chemistry of the nucleus
 Environmental: interdisciplinary, eg. Ecology, Oceanography



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 2." *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". *Antechnica*.

3) "Planck captures portrait of the young Universe, revealing earliest light". University of Cambridge. 21 March 2013. Retrieved 21 March 2013.

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?

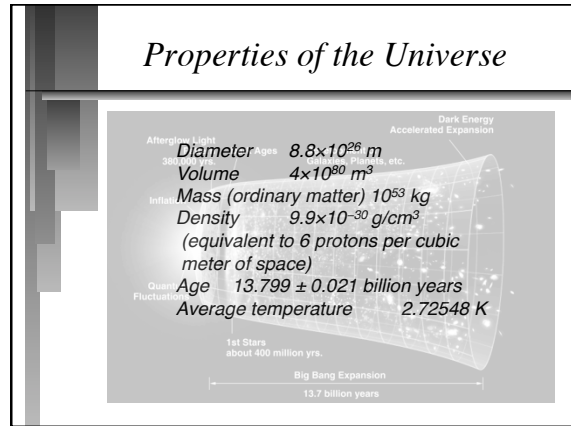
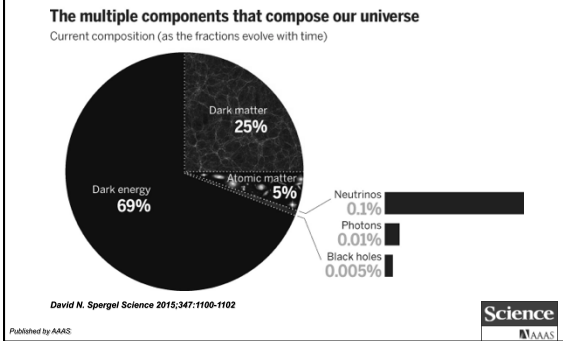
- A. YES
- B. NO

Be prepared to explain your answer.

(WSJ)



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%.



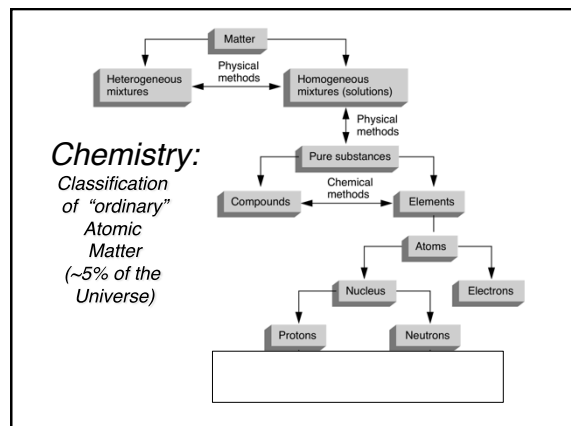
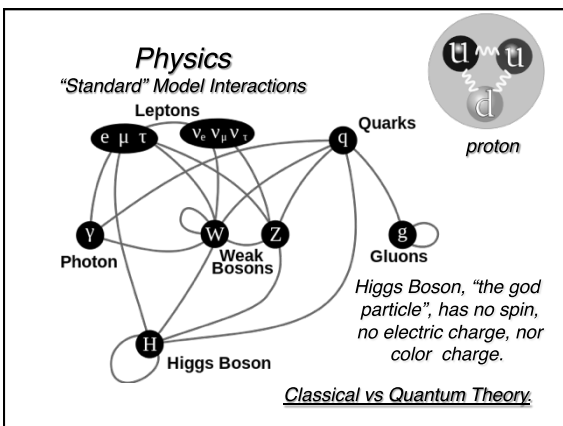
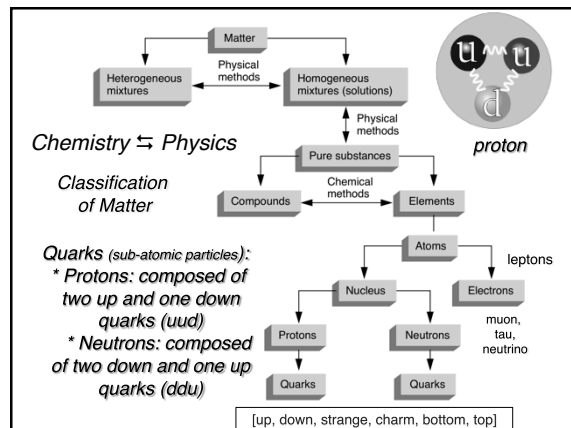
QUESTION

The multiple components that compose our universe
Current composition (as the fractions evolve with time)

Dark energy 69%
Dark matter 25%
Atomic matter 5%
Neutrinos 0.1%
Photons 0.01%
Black holes 0.005%

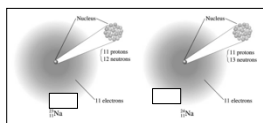
The estimated total mass of observable ordinary atomic matter in the universe is 10^{53} kg. Based on this estimate, the amount of dark matter is:

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



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

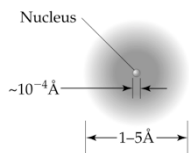
Which statement is incorrect for the three atoms in the following table.

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

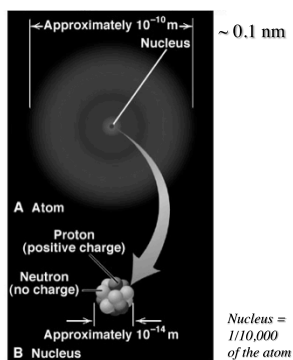
- Atoms 1, 2, and 3 have the same name.
- Atoms 1, 2, and 3 are isotopes.
- Atoms 1, 2, and 3 are ions.
- Atoms 1, 2, and 3 are not identical.

General Features of the Atom

Anders Jöns Ångström (1814-1874)
 1 Å = 10 picometers = 0.1 nanometers = 10⁻⁴ microns = 10⁻⁴ centimeters



- 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 • 1.67 x 10 ⁻²⁷ kg | +1 | H+, H, p |
| • NEUTRON | 1 amu • 1.67 x 10 ⁻²⁷ kg | 0 | n |
| • ELECTRON | very small • ~2000 x smaller than a proton or neutron | -1 | e ⁻ |

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.

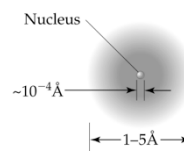
| Atom | # protons | # neutrons | # electrons |
|------|-----------|------------|-------------|
| 1 | 6 | 6 | 5 |
| 2 | 6 | 7 | 6 |
| 3 | 6 | 8 | 7 |

- Atoms 1, 2, and 3 have the same mass.
- Atoms 1, 2, and 3 have the same charge.
- Atoms 1 and 3 have the same charge.
- Atoms 1, and 3 have the same mass.
- 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" and manipulate 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
 Transmission
 Electron
 Aberration-corrected
 Microscope
 Resolution:
 +/- 0.5 Å

Atomic/molecular structures atom-by-atom

Building a quantum "corral" with Fe atoms on Cu

Xe atoms on Ni(110)

STM images courtesy of Don Eigler, IBM, San Jose

Imaging: acetylene on Pd(111) at 28 K

Molecular Image
Tip cruising altitude ~700 pm
 $\Delta z = 20$ pm

*Why don't we see the Pd atoms?
Because the tip needs to be very close to image the Pd atoms and would knock the molecule away*

TIP
 d_z
 π orbital
H
C

Calculated image
(Philippe Sautet)

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

M. Salmeron (LBL)

Surface atomic profile
Tip cruising altitude ~500 pm
 $\Delta z = 2$ pm

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

1 cm
(± 1 μ m)

Excitation of frustrated rotational modes in acetylene molecules on Pd(111) at T = 30 K

Tip
 e^-

M. Salmeron (LBL)