Scientific & Chemical Fundamentals

Dr. Ron Rusay

Scientific & Chemical Fundamentals

- Chemistry & the Scientific Method
- Matter : Classification & Properties
- Mathematics / Arithmetic:
  - Exponents, Significant Figures
- Measurement & Units: (SI & metric)
- Conversions and Relationships:
  - Dimensional Analysis: Density, Percent
- VOCABULARY: Key Terms, **Bold Style Learning**

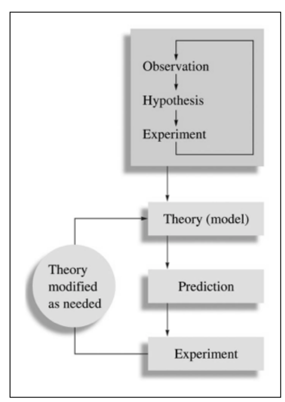
http://chemconnections.org/general/chem120/zumdahl.9e-int.html

Background Reading

Chemical Foundations

1.1: Chemical Foundations
1.2: The Scientific Method
1.3: Units and Measurements
1.4: Measurement Uncertainty
1.5: Significant Figures and Rounding
1.6: Systematically Solving Problems
1.7: Unit Conversions
1.8: Temperature
1.9: Density
1.10: Classification of Matter

Science & The Scientific Method



The 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

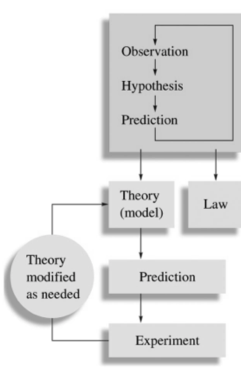
Law vs. Theory

A New Explanation of Gravity

The Case of Gravity

Law(s)? vs. Theory

Spinoza Prize €2.5 x 10^6



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.
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
   (Measurement: See Tomorrow's Lab)
   - qualitative
   - quantitative
2. Formulating hypotheses
   - possible explanation(s) for the observation
3. Performing experiments
   - gathering new information
   - testing whether the hypotheses are valid
4. Developing a theory
5. Testing & Refining

Chemistry: The Study of Matter

ð *In all of its forms & all of its behaviors*

ð *Sub-categories (not so distinct any longer)*

- *Organic: carbon*
- *Inorganic: non-carbon*
- *Organometallic: organic + inorganic*
- *Analytical: what?, how much?, how pure?*
- *Biological / Biochemistry: living organisms*
- *Physical: energy, changes, rates*
- *Nuclear: the nucleus*
- *Environmental: interdisciplinary, eg. Oceanography*

Chemistry & Matter (Chemicals)

ð *How many different chemicals do you think have been reported in the scientific literature?*

A) 100,000
B) 1,000,000
C) 10,000,000
D) 100,000,000
E) 1,000,000,000

Chemistry & Matter:
Properties & States

- *Physical vs. Chemical Properties*
- *Solid (s), Liquid (l), Gas (g)*
- *Homogeneous vs. Heterogeneous Mixtures*
- *Organization of atoms/molecules: atoms/elements → molecules/compounds*
- *Extensive vs. Intensive Properties*

  Varies with amount (extensive) or does not vary with amount (intensive)

  Heat of reaction is extensive, density is intensive

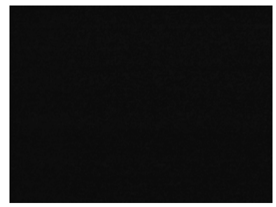
QUESTION

Extensive properties of a pure substance depend on sample size whereas intensive properties are characteristic of that substance. Which of these properties are intensive?

I) Color
II) Mass
III) Density

A) I and II B) I and III C) II and III D) I, II and III

Observations of Physical & Chemical Properties



Physical-Chemical Properties Movie

QUESTION

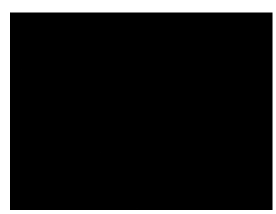
Which of these are chemical properties of matter?

I) Corrosiveness
II) Density
III) Flammability
IV) Melting point

A) I and II B) I and III

C) II and IV D) III and IV

States of Matter



States of Matter Movie

Matter & Energy

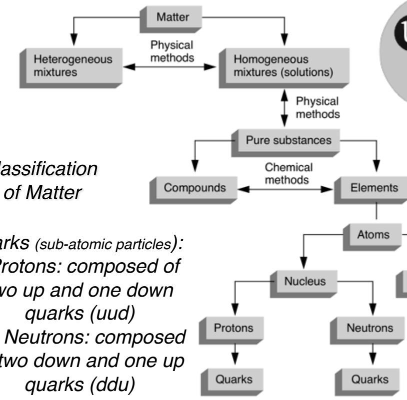
$E = mc^2$

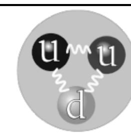
http://energy.gov/articles/livestream-our-latest-nobel-prize-winner

Based on the standard model of cosmology, the total mass/energy of the universe is comprised of 4.9% ordinary (Chem 120) 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 its emitted 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.





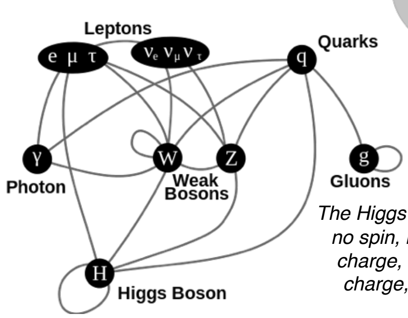
proton

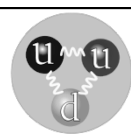
Classification of Matter

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]

Physics "Standard" Model Interactions

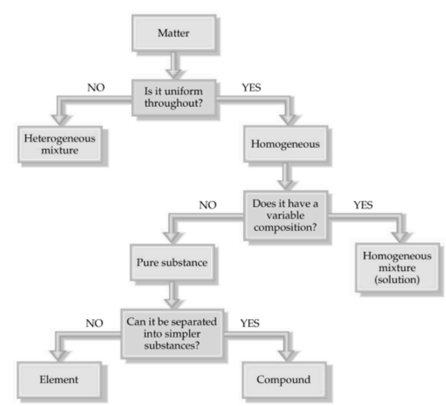




proton

The Higgs Boson has no spin, no electric charge, nor color charge, Google:

Classical vs Quantum Theory.



QUESTION

Which of these atomic and/or molecular views represent pure substances?

A) I and III ***B) II and IV***

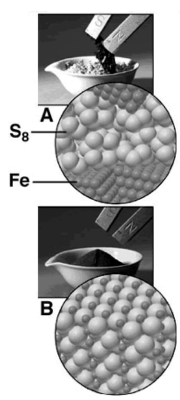
C) I, II and IV ***D) II, III, and IV***

Using Physical & Chemical Properties:
Distinguishing a Compound & a Mixture

Mixtures and Compounds

Mixtures and Compounds Movie

The effects of a magnet on iron: filings in a mixture and atoms in a molecule.



Chemical Separations

Types of Mixtures

- *Mixtures have variable composition of two or more components.*
- *A homogeneous mixture is a solution (for example, vinegar: water + acetic acid, or steel & bronze: solid metals)*
- *A heterogeneous mixture is, to the naked eye, clearly not uniform (for example, a bottle of ranch dressing with two layers: water + oil, or two solids: iron and sulfur)*

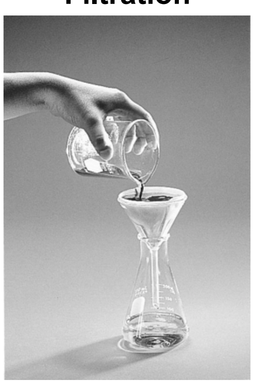
Separating Mixtures

- ***Filtration:*** *Separates components of a mixture based upon differences in particle size. Examples: a precipitate from a solution, or particles from an air stream.*
- ***Crystallization:*** *Separation based upon differences in solubility of components in a mixture. Ideally the impurities are much more soluble in the solvent than the material being purified.*
- ***Distillation:*** *Separation based upon differences in volatility (boiling points) of components in a homogeneous mixture. Example: ethanol & H_2O*

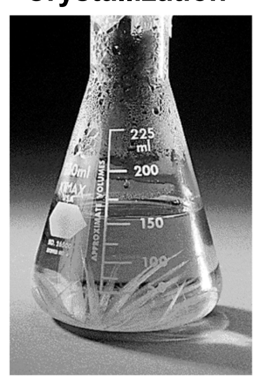
Separating Mixtures

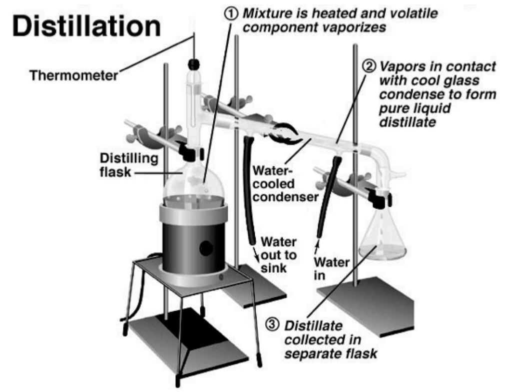
- ***Extraction:*** *Separation based upon differences in a compound's solubility between two different solvents, typically immiscible liquids. Examples: ether & H_2O, gasoline (hydrocarbons) and water.*
- ***Chromatography:*** *Separation based upon differences a compound's solubility in a solvent versus a stationary phase. Examples: paper, thin layer (TLC), column, gas-liquid (GC); liquid-liquid: (HPLC), reverse phase.*

Filtration

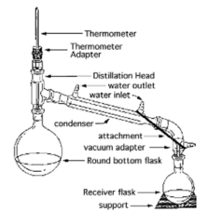


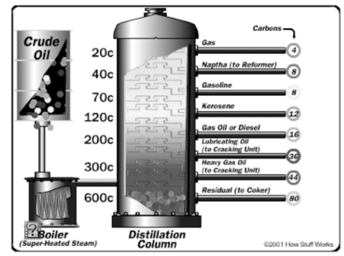
Crystallization



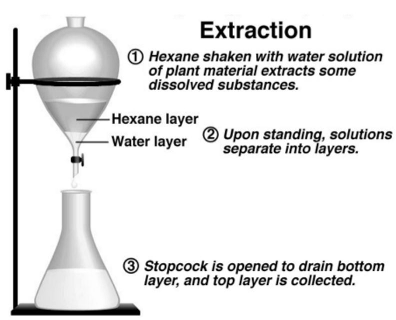


Closer to actual apparatus

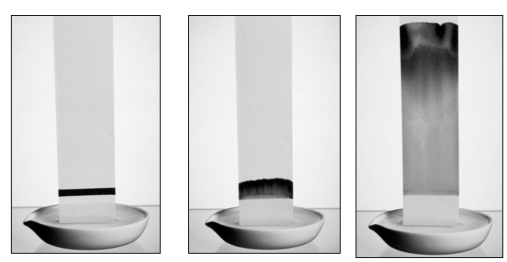




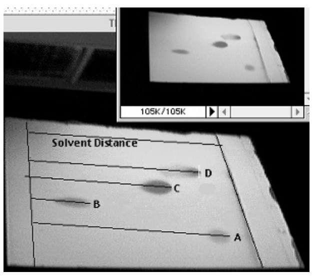
Oil Refining:
http://science.howstuffworks.com/oil-refining4.htm



Paper Chromatography

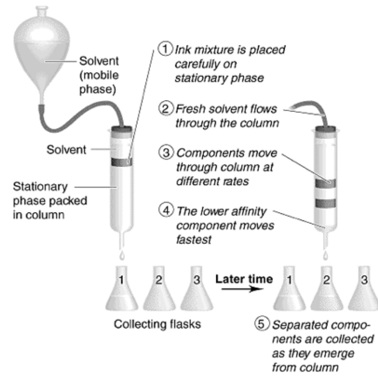


Thin Layer Chromatography

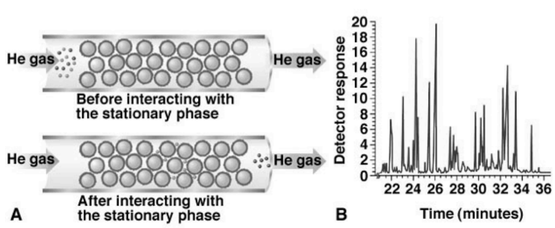


Stationary phase: silica or alumina

Procedure for Column Chromatography



Principle of Gas-Liquid Chromatography

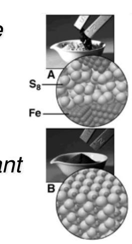


Elements & Compounds

Element: A substance that cannot be broken into simpler substances by chemical means, eg. Fe, Iron or S_8 Sulfur

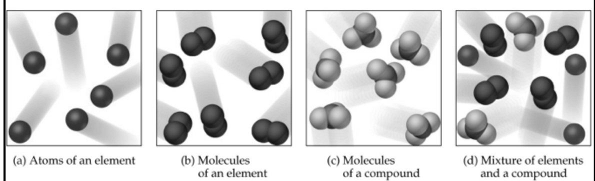
Elements in Song

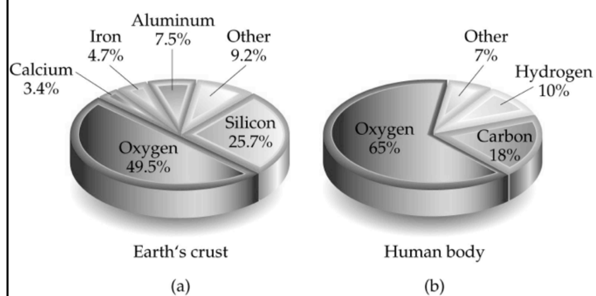
Compound: A substance with a constant composition that can be broken down into elements only by chemical processes,eg. FeS, Iron (II) sulfide



Atomic / Molecular Visualization

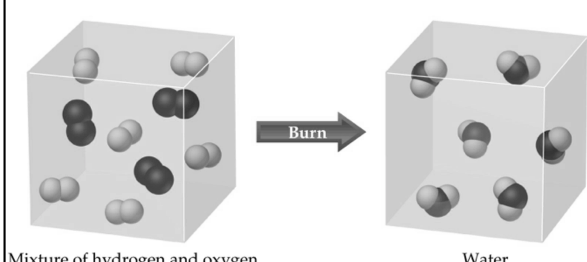
Atomic Force Microscopy / Molecular Modeling
Experimental / Mathematical





Three Balloons

The red spheres are oxygen and the white/gray are hydrogen.



How many oxygens are there? How many hydrogens are there?	How many oxygens are there? How many hydrogens are there?

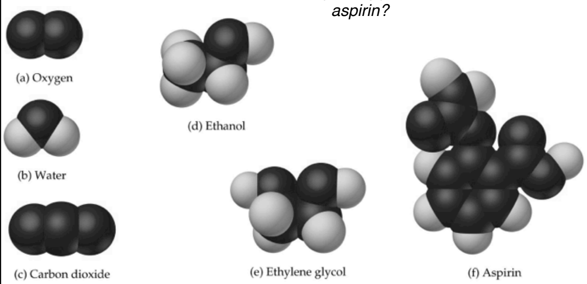
$6\ H_2(g) + 3\ O_2(g) \rightarrow 6\ H_2O(l)$

QUESTION

The electrolysis of water is the reverse of burning (combustion). Which equation best represents the change that takes place when water is electrolyzed?

A) $H_2O(l) \rightarrow H_2O(g)$
B) $H_2O(g) \rightarrow H_2O(l)$
C) $2\ H_2O(l) \rightarrow 2\ H_2(g) + O_2(g)$
D) $2\ H_2(g) + O_2(g) \rightarrow 2\ H_2O(l)$

How many hydrogens, oxygens, and carbons are there in:
ethanol?
ethylene glycol?
aspirin?



The red spheres are oxygen, the white/gray are hydrogen, and black carbon.

QUESTION

Is a cup of coffee a homogeneous solution or a compound? Which of the following agrees with your reasoning?

A. The coffee in the cup is a homogeneous solution because it contains the same components throughout, but there are many compounds dissolved to make coffee.
B. The coffee in the cup is a compound because it has a set ratio of components that make it the same throughout.
C. The coffee in the cup is both a compound and a solution.
D. It looks the same throughout like a true solution, yet it always has the same amount of each component.
E. The coffee in the cup is a heterogeneous solution not homogeneous because it contains distinct, different compounds dissolved to make coffee.