GENERAL CHEMISTRY I - Chem 205

Lectures 1-2:	Week 1, Sept. 2nd - 6th, 2013 Fall (sect. 01)
Topics:	Kotz 8th Ed. Ch.1 & "Let's review" quantitation
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WHY STUDY CHEMISTRY ?

- learn how substances tend to behave, & why
- learn to figure out how everyday stuff works

BUILD SKILLS:

- learn to think on multiple levels
- learn to apply knowledge
- learn to attack problems

GENERAL CHEMISTRY I - Chem 205

• Chemistry is often referred to as the "central science".

• Chemistry has a long history as humans have long tried to understand the nature of the material world.

•Alchemist were the first chemists

GENERAL CHEMISTRY I - Chem 205

By learning the fundamentals of chemistry, you'll learn to address real world questions…

- Why does ice float? & Is this *normal*?
- What is battery acid? & Why is it in there?
- How do neon signs work?
- What will help get a grease stain out?
- How do air bags work?

Chemistry - think small to understand the big picture

macroscopic ⟷ microscopic (not small enough) ⟷ particulate

Graphite: slippery

WHY?

- layered structure of carbon atoms
- layers can slide!

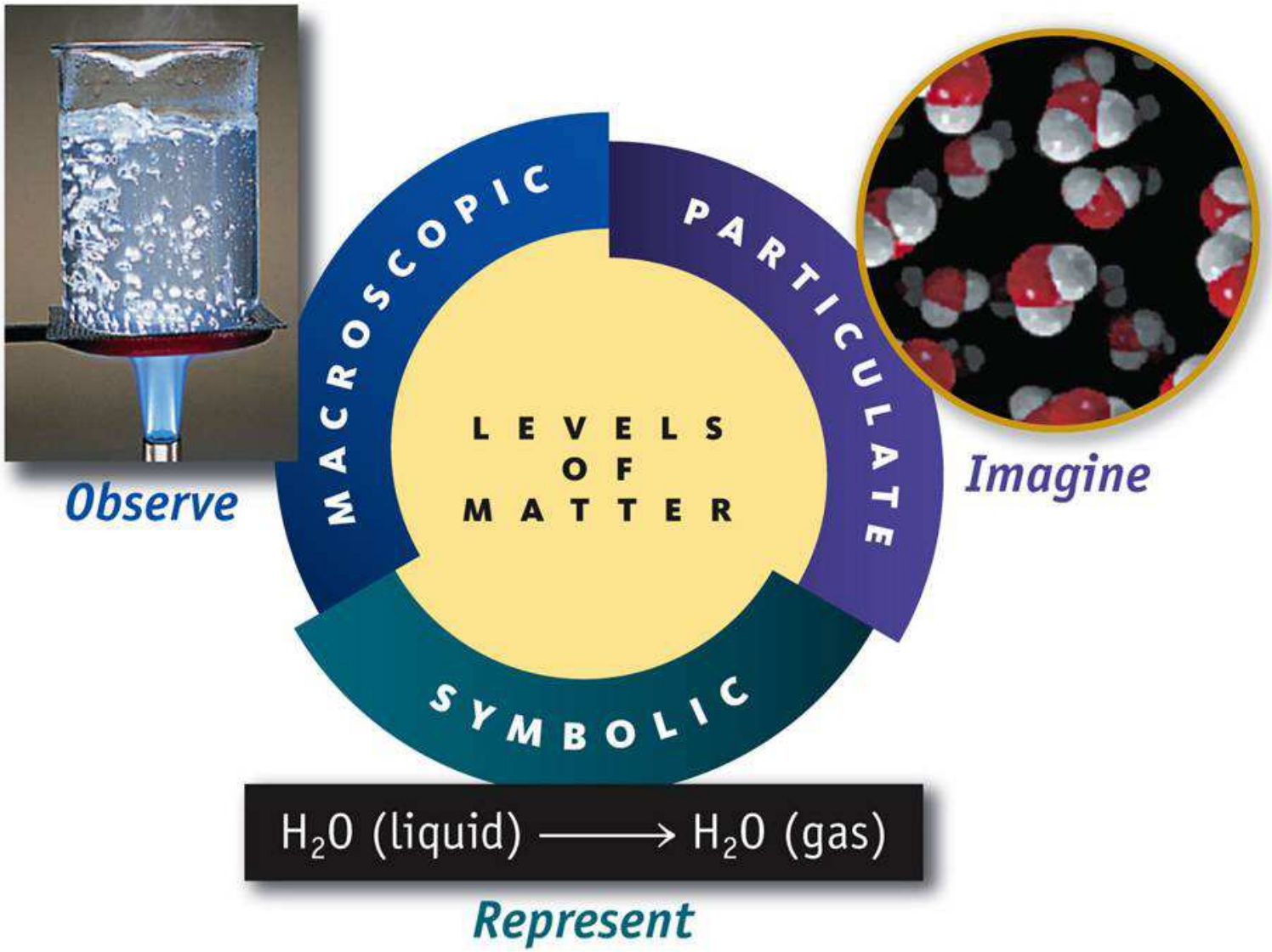
How is behaviour related to composition?

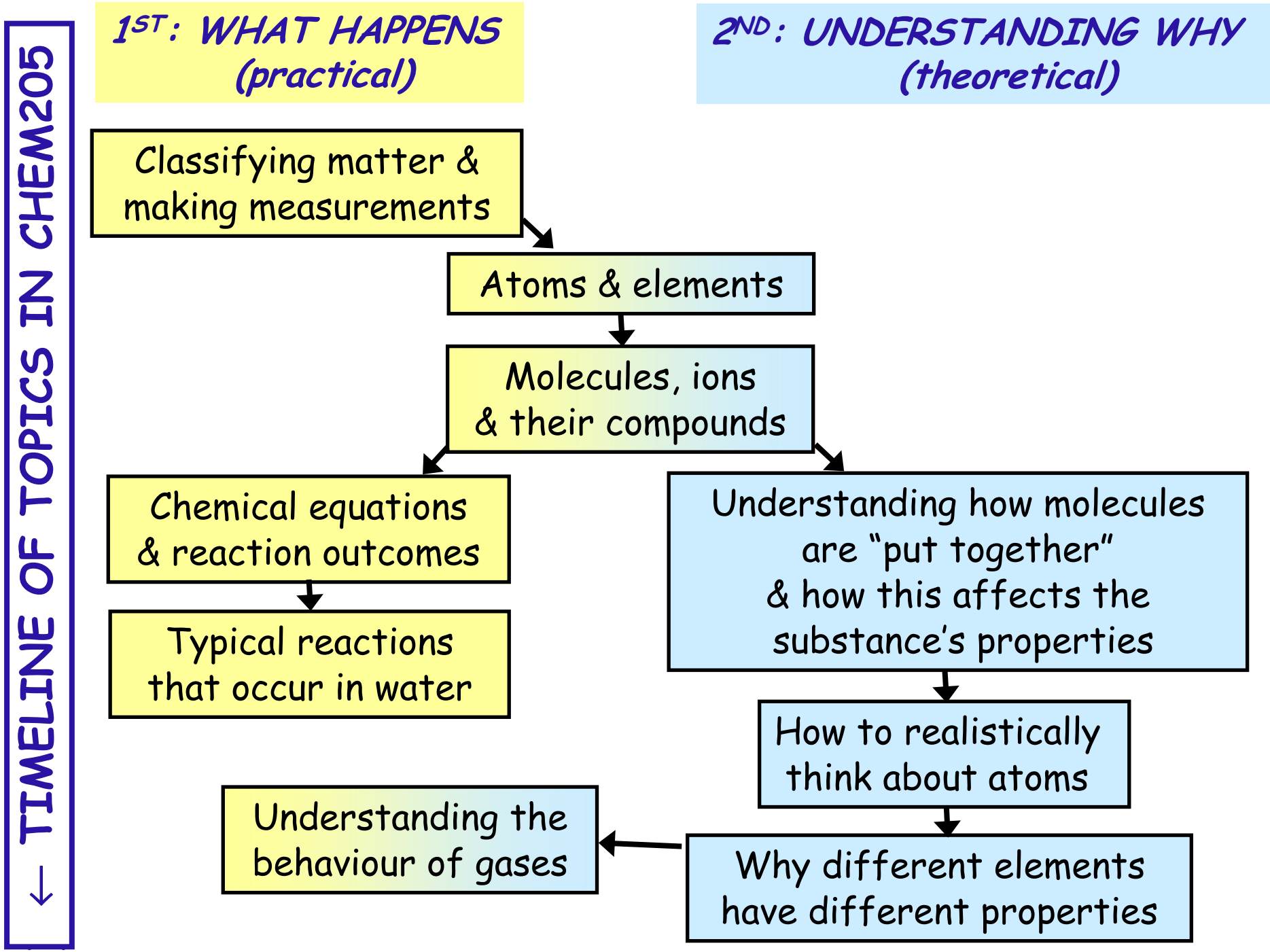
- What are the substance's fundamental building blocks?
- How they are arranged?

Can we manipulate composition to get results we want?

- Pharmaceuticals, plastics, preservatives, paints, *etc…*

The different levels of chemical thinking (Kotz Fig.1.6)




← TIMELINE OF TOPICS IN CHEM205
1ST: WHAT HAPPENS (practical)
2ND: UNDERSTANDING WHY (theoretical)
Classifying matter & making measurements
Atoms & elements
Molecules, ions & their compounds
Chemical equations & reaction outcomes
Typical reactions that occur in water
Understanding how molecules are "put together" & how this affects the substance's properties
How to realistically think about atoms
Why different elements have different properties
Understanding the behaviour of gases

Ch.1: Reviewing the basic concepts of chemistry

1.1 Chemistry & its methods
1.2 Sustainability *(on your own)*
1.3 Classifying matter
1.4 Elements & atoms
1.5 Compounds & molecules
1.6 Physical properties
1.7 Physical & chemical changes
1.8 Energy: some basic concepts

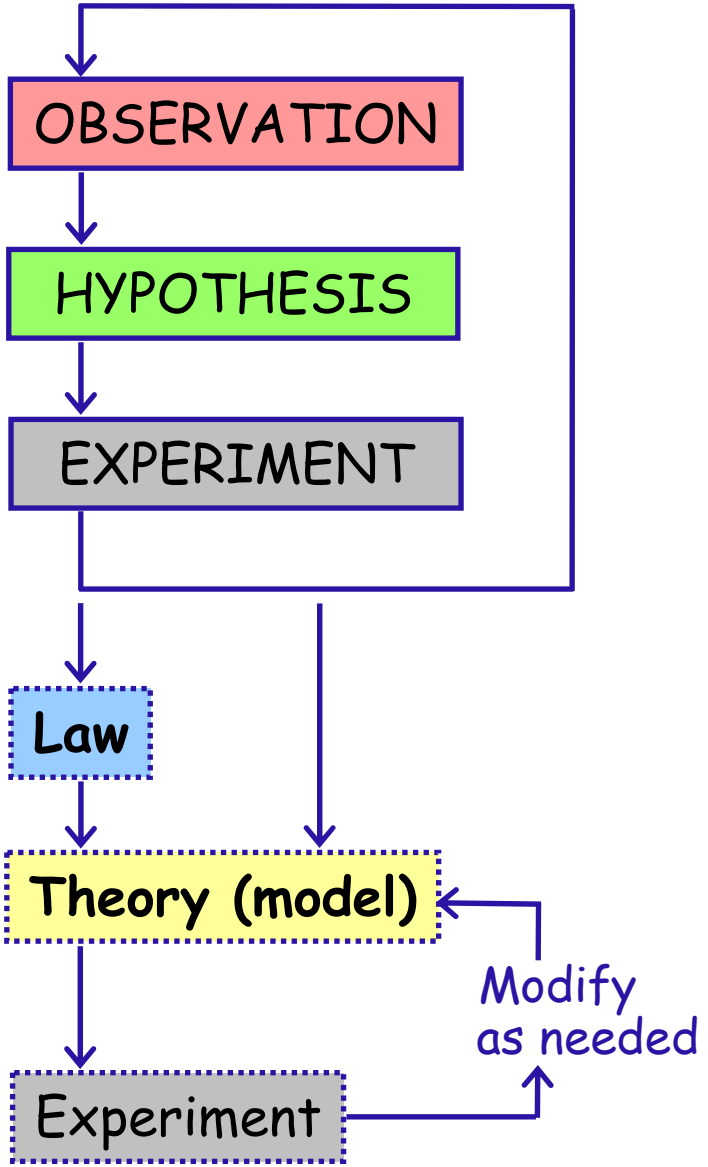
"Let's review": quantitation
1 Units of measurement
2 Precision, accuracy & exp'tal error
3-6 Math & problem-solving in chemistry

Order (not always same as text):
Start with: qualitative aspects
sections 1.1-1.8
Next class: quantitative aspects
"Let's review" 1-6

Chapter Goals:
1. **Classify matter**
2. **Recognize elements, atoms, compounds, molecules**
3. **Identify physical & chemical properties & changes**
4. **Apply the kinetic-molecular theory to the properties of matter**
5. **Use metric units & significant figures correctly**
6. **Understand & use the maths of chemistry**

1.1 The Scientific Method

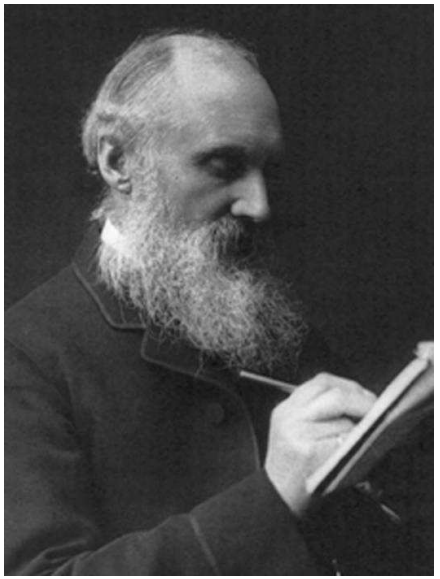
- Qualitative / Quantitative
- Tentative explanation
- Systematic, controlled observations / measurements
- Verbal / mathematical description of **WHAT HAPPENS**
- Model proposed to explain **WHY** the behaviour occurs



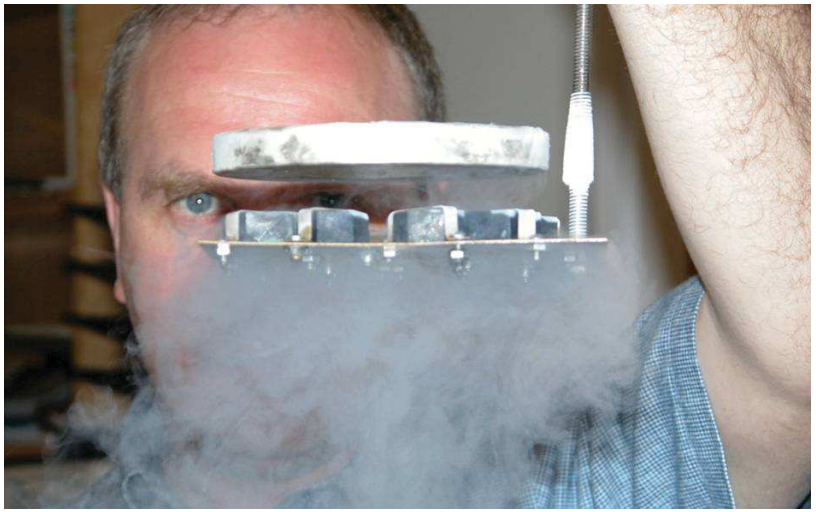
From: *Chemistry – Principles, Patterns & Applications*, by B.Averill & P. Eldredge; Pearson; 2007.

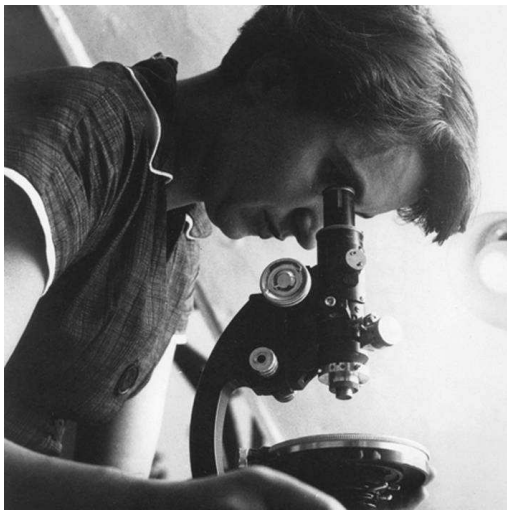
Reporting results to other scientists (including teachers)

- Experimental results should be reproducible.
- Results should be reported in sufficient detail that they can be used or reproduced by others.
  - student lab results: in notebooks & reports
  - research results: in the scientific literature
- Conclusions should be reasonable & unbiased.
- Credit should be given where it is due.



Images from: Kotz 8th Ed.





1.3 Classifying matter: States of matter (a particulate view)

Kotz 6th Fig. 1.5
BROMINE (Br_2) in its 3 STATES:

SOLIDS

- rigid shape, fixed volume.
- external shape can reflect particles' arrangement.
- behaviour is reasonably well understood.

LIQUIDS

- fluid shape, but fixed volume.
- behaviour is not well understood (*i.e.*, complicated).

GASES

- expand to fill their container.
- behaviour very well understood (& simple).

See Ch. 11

1.4 Elements & atoms

(details? Ch. 2, 6, 7)

CHEMICAL ELEMENT:

- pure substance that <u>cannot be subdivided</u> into any other substances via physical or chemical methods *(details about methods soon…)*
- building blocks: composed of only ONE kind of atoms

Fig. 1.6

Hg(ℓ) **S(s)** **Cu(s)** **Fe(s)** **Al(s)**

1.5 Compounds & molecules *(details? Ch. 2, 8)*

COMPOUND:

- pure substance that requires chemical means to be further subdivided
- cannot separate into parent elements via physical separation methods
- building blocks: composed of 2 or more elements in fixed ratio

Fixed composition: specific proportions of elements, represented by…

1) chemical formula
   = atom-to-atom ratio

2) percent composition
   = % each element by mass

Water: H_2O

In 100g of water:
11.2 g due to H atoms, 88.8 g to O atoms
(as part of molecules, not free atoms)
i.e., 11.19% H & 88.81% O by mass

Characteristic properties: different from parent elements

Water: H_2O
Non-flammable liquid

vs.

Hydrogen: H_2
Highly flammable gas

Oxygen: O_2
Combustion-supporting gas

Chemical means are required to break down compounds into their constituent elements

- **"Redox" reactions**
  (see Ch.4)

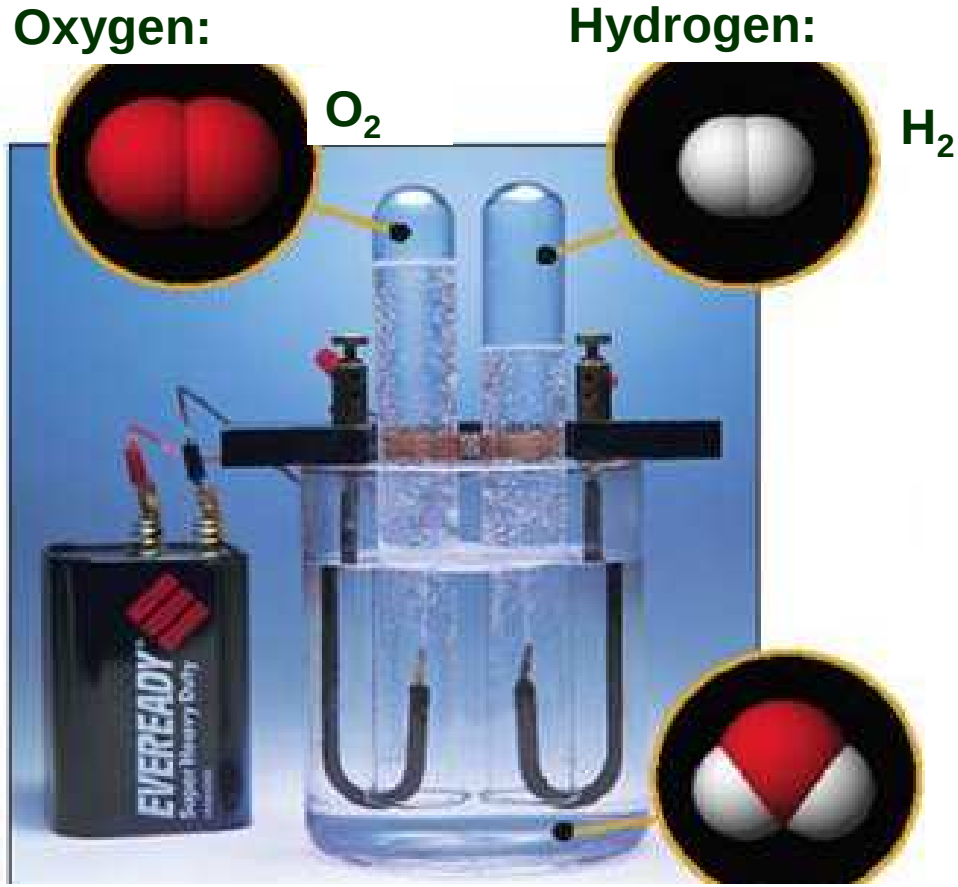
e.g., **Electrolysis:**
pass high current through liquid water to decompose it:

$2\ H_2O(\ell) \rightarrow 2\ H_2(g) + O_2(g)$

SIMILARLY:

pass high current through molten salt to decompose it:

$2\ NaCl(\ell) \rightarrow 2\ Na(s) + Cl_2(g)$



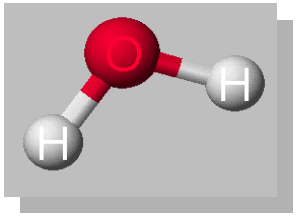
Kotz 6th Ed., Fig. 1.6

Building blocks for compounds

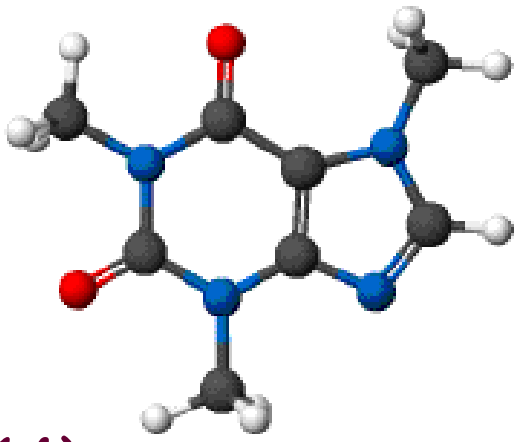
= smallest group of atoms / ions that retains BOTH the composition & characteristics of the compound

COVALENT COMPOUNDS

MOLECULE = atoms bonded together into discrete unit



Water
H_2O

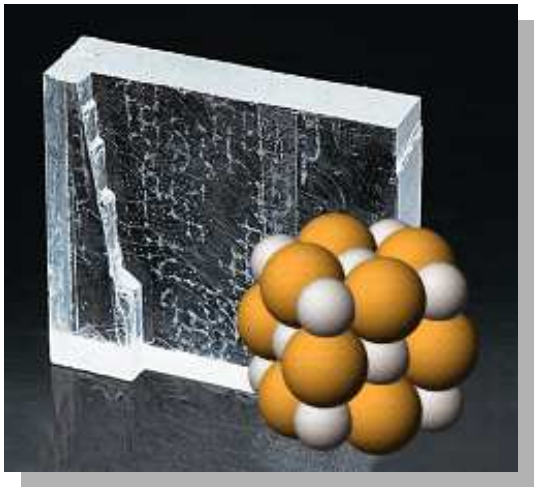


Caffeine
$C_8H_{10}N_4O_2$

IONIC COMPOUNDS

IONS = electrically-charged atoms or groups of atoms

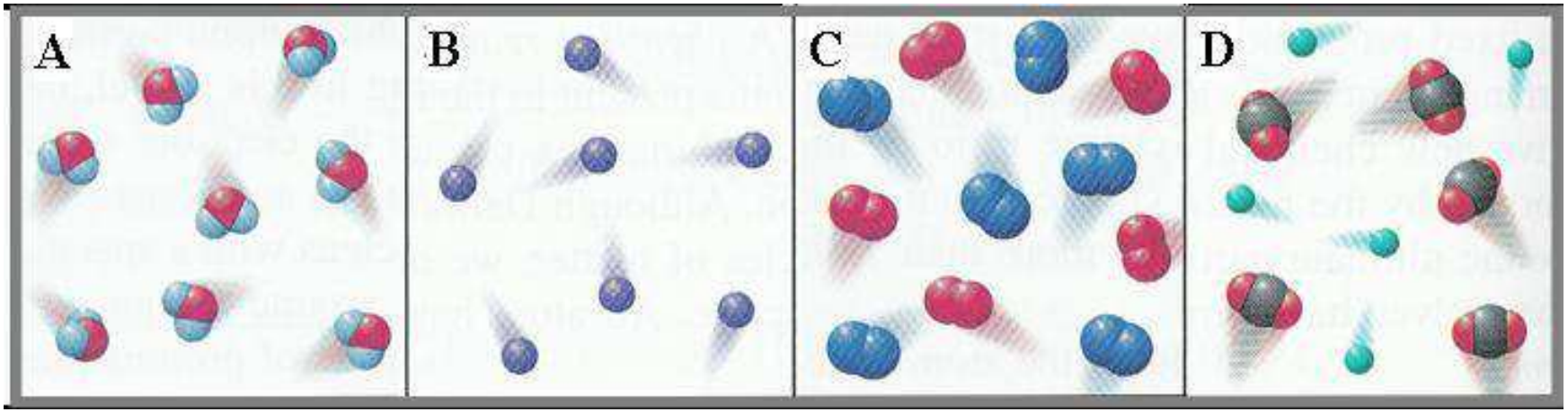
Common salt NaCl



CLICKER Q: identify substance type by its building block

The figures below represent four different samples of gas-phase matter.

Which one represents a mixture of two elements ?

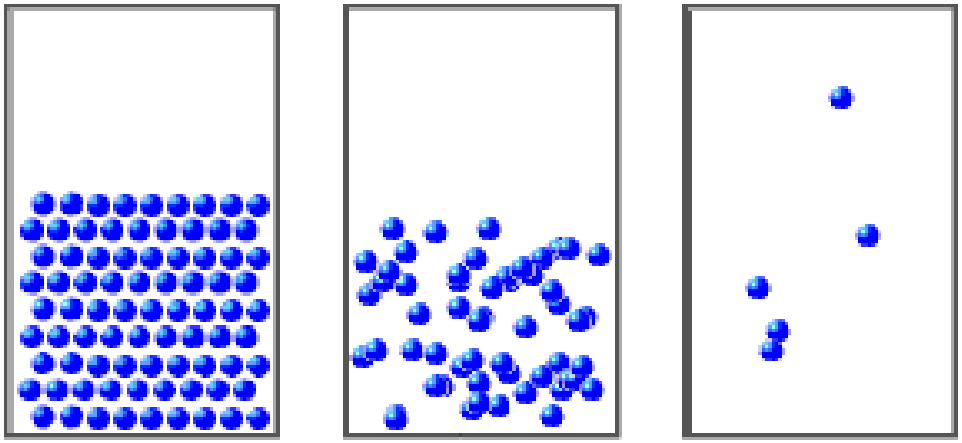


Matter consists of atoms & molecules (particles!) in constant motion.

1.8 Energy: some basic principles (more in Chem 206)

- Energy can be classified as ***Potential*** or ***Kinetic***
- ***Potential energy*** = energy associated with position, including…
  - *gravitational E:* an object held at a height, waterfalls.
  - *chemical energy:* energy stored in molecules, due to bonds between atoms
  - *electrostatic E:* energy due to attractions between charged or partially charged particles
  - *nuclear energy:* energy associated with attractions between nuclear particles (released via fission, fusion)
- ***Kinetic energy*** = energy associated with motion, including…
  - *mechanical energy:* movement of a macrosopic object (*e.g.,* ball)
  - *thermal energy:* motion at the particulate level
  - *electrical energy:* movement of electrons in a conductor
  - *acoustic energy:* compression-type wave motion

Matter consists of particles in constant motion.
– Kinetic Molecular Theory



Kinetic energy ∝ Temp.

i.e., higher temperature

↘

faster motion

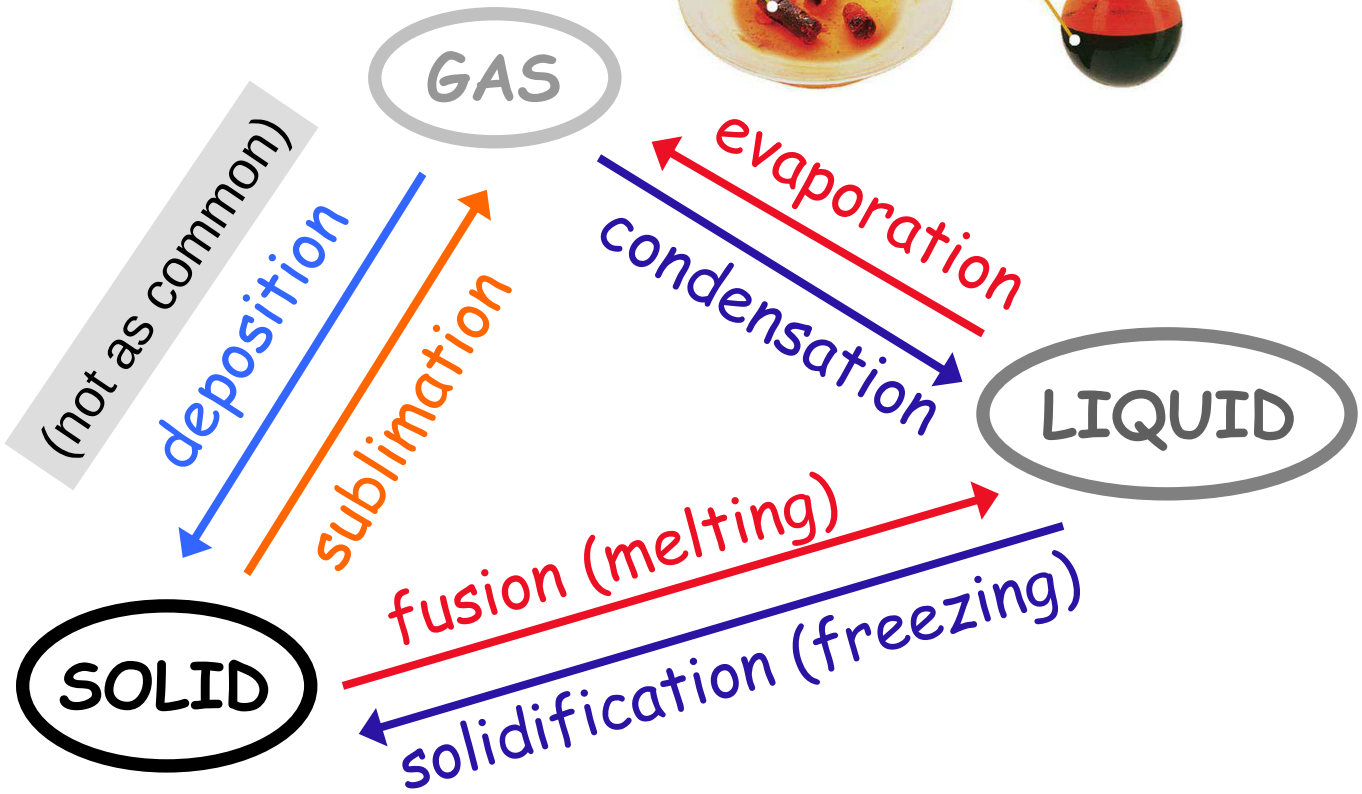
- Between particles: **forces of attraction** (details in Chem 206)…
- Low temperatures: matter usually solid
  - *WHY?* K.E. is low ∴ attractive forces seem large
- Higher temperatures: change to liquid…or gas…
  - *WHY?* Higher K.E. ∴ can overcome attractions

Physical change *e.g.*, phase changes (changes of state)

- Change in organization of particles, but NOT composition
- Temperatures at which changes occur are characteristic properties
  - *E.g.*, bromine: m.p. -7.2°C, b.p. +58.8°C

When particles move closer together: energy released as heat

When particles are forced farther apart: energy input required



Making observations: always describe <u>before</u> AND <u>after</u>

Qualitative observation = describing things

1.6 Physical properties

see Table 1.1

How can we identify a substance (if it's pure)?

Can observe & describe…without changing its composition

- Colour, odour
- State of matter: ***Gas? Liquid? Solid?***
- Appearance: ***Shape? Powdered? Crystalline? Transparent?***
- Melting point, boiling point
- Solubility: ***How much will dissolve? In what will it dissolve?***
- Electrical conductivity: ***conductor vs. insulator?***
- Malleability: ***easily deformed?***
- Ductility: ***easily drawn into a wire?***
- Viscosity: ***for liquids: thick or thin? Does it flow easily?***
- Density: ***mass per unit volume***

CLICKER Q: describing properties

A large block of crystalline table salt (sodium chloride, NaCl) is shown.

Which choice correctly describes the appearance of this substance?

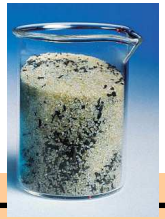
A. Clear & colourless
B. Opaque & colourless
C. Translucent & colourless
D. Transparent & colourless
E. Both A & D

Other physical properties of NaCl include:

- brittle
- water-soluble
- conductive when melted or dissolved

Classifying matter: mixtures *vs.* pure substances

Matter: solid, liquid or gas
- anything that fills space & has mass



Heterogeneous matter:
- non-uniform in appearance
- always a mixture of substances

PHYSICALLY SEPARABLE INTO →

Homogeneous matter:
- uniform appearance
- but might be a mixture

Solution:
- uniform mixture of substances
- widely variable compositions

PHYSICALLY SEPARABLE INTO →

Pure substance:
- fixed composition
- cannot be further purified

Element:
- cannot be subdivided via chemical OR physical means

REACT CHEMICALLY TO FORM →

← CHEMICALLY SEPARABLE INTO

Compound:
- cannot be subdivided via physical methods
- elements in fixed ratios

Separating heterogeneous mixtures: by filtration

(a physical method)

Kotz 8th Figure 1.9

industrial scale

heterogeneous liquid - solid mixture

homogeneous liquid filtrate

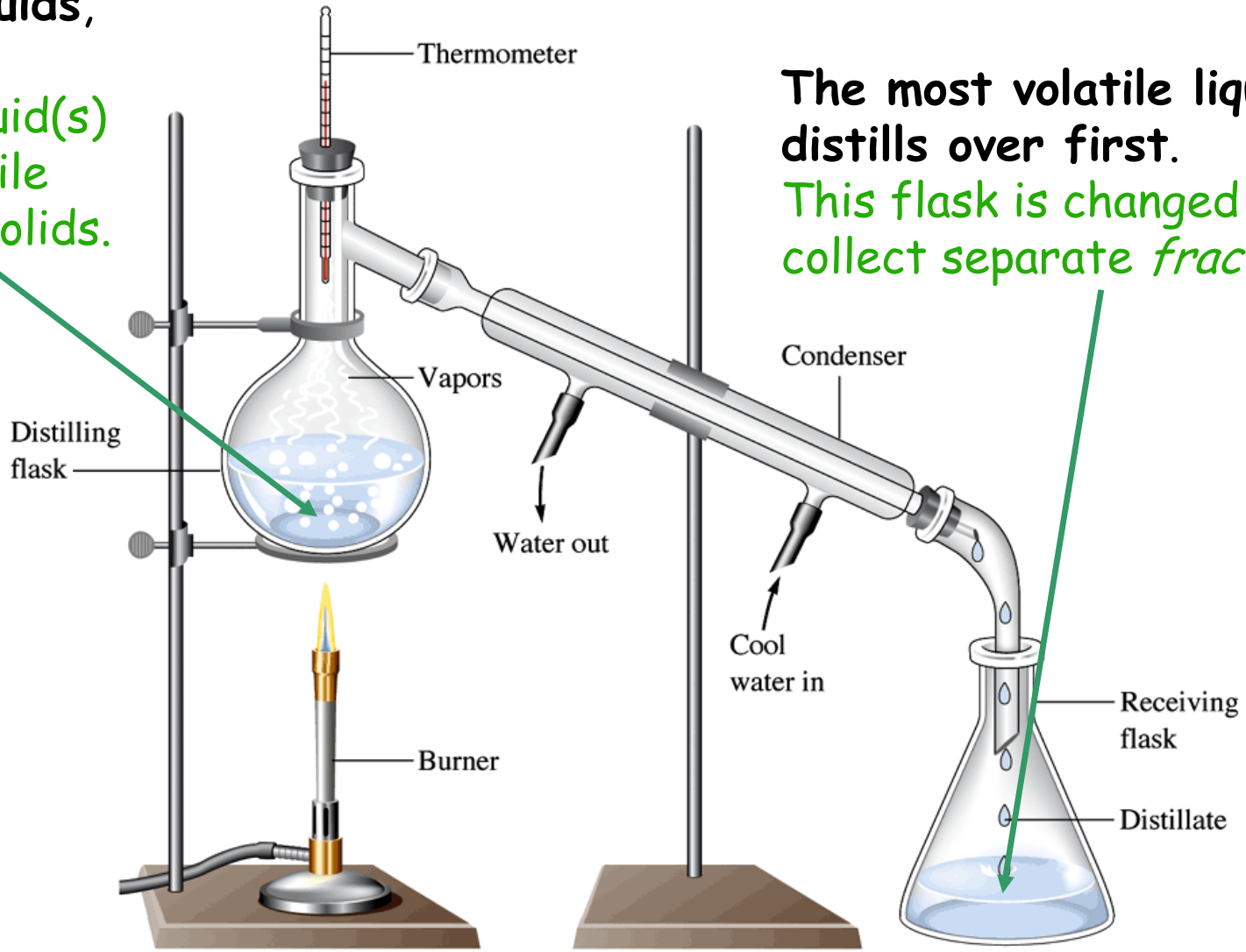
→ to further purify:
…evaporate solvent
& collect residue

Separating homogeneous mixtures: by distillation

(a physical method)

A mixture of volatile liquids, or perhaps volatile liquid(s) and involatile dissolved solids.

The most volatile liquid distills over first. This flask is changed to collect separate *fractions*.

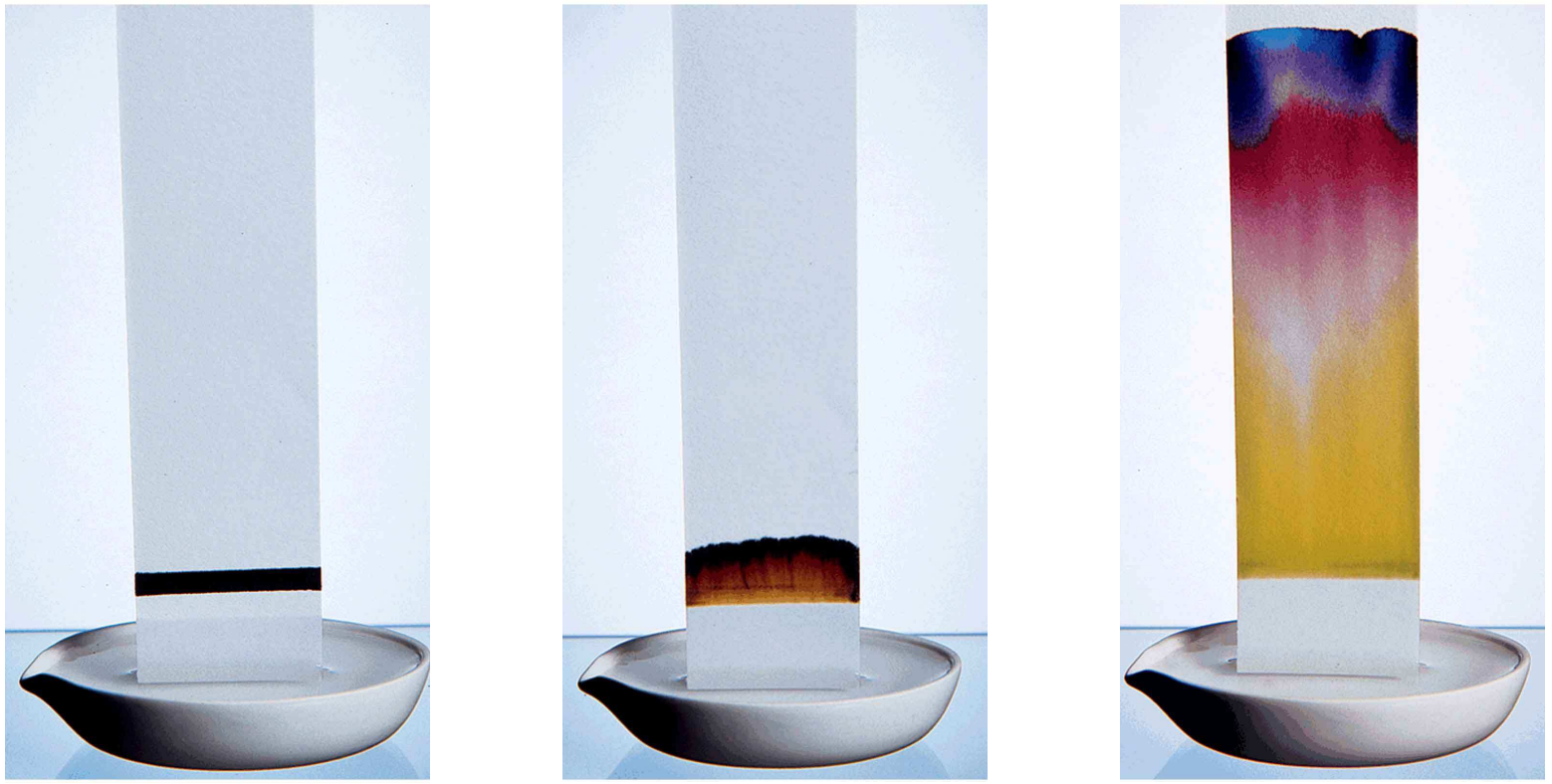


Picture taken from Zumdahl

Separating homogeneous mixtures: by chromatography

(a physical method)

- **PURPOSE:** to determine how many components are in mixture,
  to test purity, or before attempting large scale separation



Images from Zumdahl

- **Analyte:** a mixture of coloured dyes (black ink)
- **Stationary Phase:** filter paper (porous paper)
- **Mobile phase:** probably a mixture of water and alcohol

CLICKER Q: separating a mixture

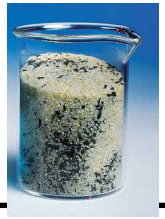
The beaker contains a solution of a nonvolatile blue solid, copper sulfate ($CuSO_4$), dissolved in water.

Which method below would separate the mixture into its two components, such that you would end up with a pure sample of each substance?

A. Distillation
B. Filtration
C. Chromatography
D. None of the above will work

Classifying matter: mixtures *vs.* pure substances

Matter: solid, liquid or gas
- anything that fills space & has mass



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PHYSICALLY SEPARABLE INTO →

Homogeneous matter:
- uniform appearance
- but might be a mixture

Solution:
- uniform mixture of substances
- widely variable compositions

PHYSICALLY SEPARABLE INTO →

Pure substance:
- fixed composition
- cannot be further purified

Element:
- cannot be subdivided via chemical OR physical means

REACT CHEMICALLY TO FORM →

← CHEMICALLY SEPARABLE INTO

Compound:
- cannot be subdivided via physical methods
- elements in fixed ratios

1.7 Physical change *vs.* chemical change

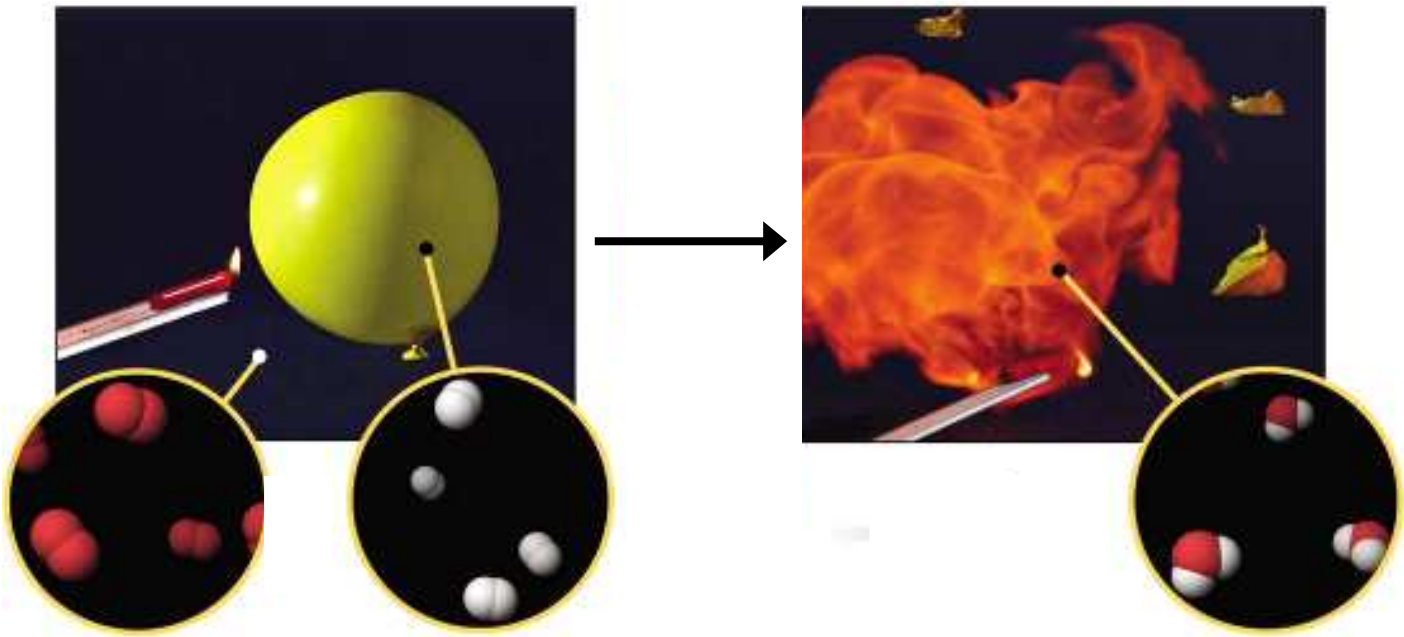
Change in organization of atoms/molecules/ions	Change in composition of atoms/molecules/ions
WHY: Change in interactions between molecules	*WHY:* Rearrangement of bonds between atoms/ions
Identity of substance(s) UNCHANGED	Identity of substance(s) CHANGED
melting butter **dissolving sugar** **boiling water**	**burning butter** **digesting sugar** **reacting water with Na(s)**
BOTH often involve transfers of energy: release (or absorption) of HEAT or LIGHT	

Chemical change: change in composition

- Chemical reactions involve REARRANGEMENT of bonds between atoms…but not net loss/gain of atoms

Macroscopic view:

Particulate view:



Symbolic view:

$2\ H_2(g) + O_2(g) \longrightarrow 2\ H_2O(g)$

Reactants — Chemical change — Products

Fig. 1.16

Chemical properties: rxns typical of a substance

- Rusting -- of iron
- Combustion -- of wood, gasoline "organic materials"
- Tarnishing -- of silver
- Hardening -- of cement
- Violent reaction with water
  - *E.g.*, potassium metal →

Kotz 8th p.23

Making observations: Always describe <u>before</u> AND <u>after</u>

CLICKER Q: physical *vs* chemical change

Fig. 2.10

Consider the following statements about sulfur (S), a yellow non-metallic element.

1) Sulfur is produced commercially by injecting steam into underground sulfur deposits to melt it.
2) It is then carried by the steam to the surface, where the sulfur separates from the water after cooling.
3) Sulfur burns in oxygen to form a choking gas, SO_2, which reacts with water to form acid rain.

Which statements describe(s) a chemical reaction ?

Kotz p.133

A. Statement 2 only.
B. Statement 3 only.
C. Statements 1 & 2.
D. Statements 2 & 3.
E. All of them.

CLICKER Q: understanding a common observation

A student slowly heats some water (H_2O) in a beaker. When the water reaches 30°C, bubbles begin to form on the walls of the beaker and eventually float to the surface. At 100°C, bubbles form rapidly throughout the water as it boils. Which option (A-E) describes the composition of the bubbles at the two temperatures?

	At 30 °C AND	At 100 °C
A	water vapour $H_2O(g)$	hydrogen $H_2(g)$ & oxygen $O_2(g)$
B	water vapour $H_2O(g)$	hydroxide ion $OH^-(g)$ & hydrogen ion $H^+(g)$
C	air (N_2 & O_2 gases) & a little $H_2O(g)$	water vapour $H_2O(g)$
D	water vapour $H_2O(g)$	air (N_2 & O_2 gases) & a little $H_2O(g)$
E	carbon monoxide $CO(g)$ & oxygen $O_2(g)$	carbon dioxide, $CO_2(g)$

PHASE CHANGE: (a physical change)

$H_2O(\ell)$ **Water** —Physical change→ $H_2O(g)$ **Water vapour (steam)**

Quantitative observations = measuring things

Properties with numerical values do not necessarily reflect the sample's size.

Intrinsic properties *vs.* extrinsic properties

(intensive) (extensive)

Characteristics of the substance itself, not the quantity

- Density
- Melting point
- Boiling point
- Viscosity *etc…*

Properties that depend on the quantity of substance present:

- Mass
- Volume
- Length, width, height…

Is temperature an intrinsic or extrinsic property?

Scientific temperature scales

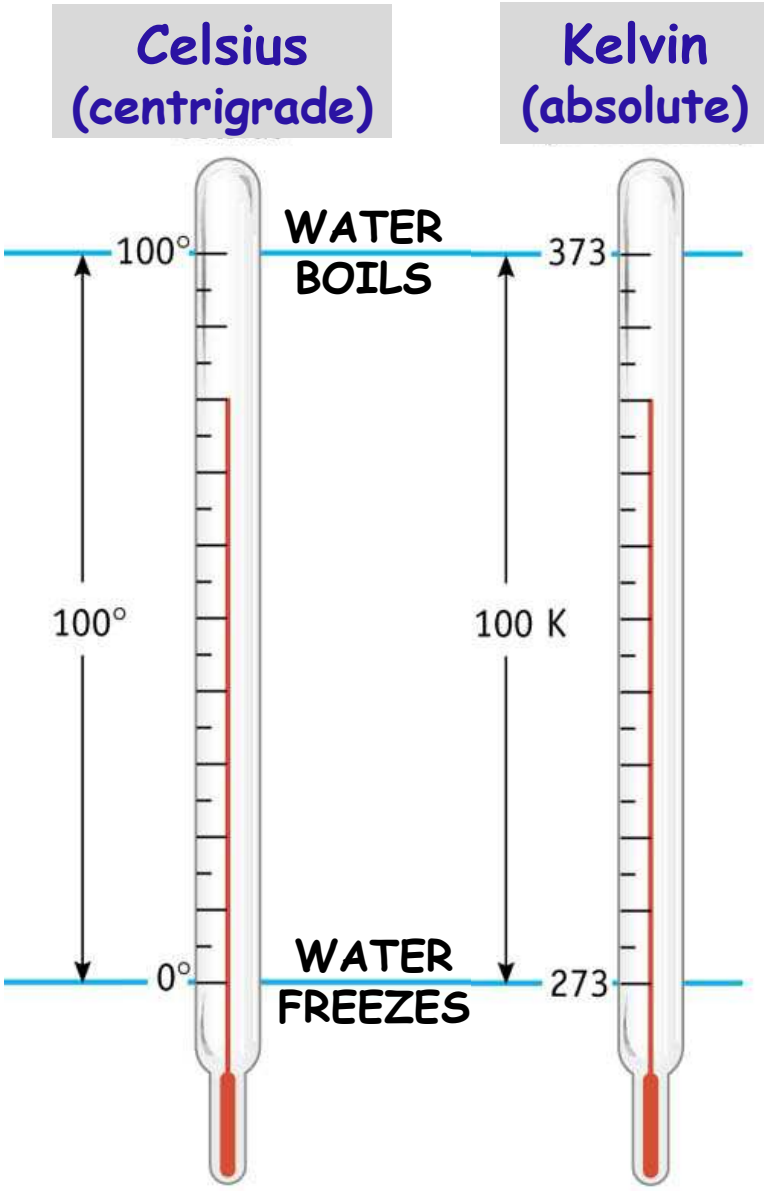
Celsius & Kelvin units are same size, but OFFSET:

$$T_K = T_C \times \frac{1\ K}{1^\circ C} + 273.15\ K$$

Absolute zero = 0 K = _____ °C

Liquid N_2 boils at 77 K = _____ °C

Room temperature = ___ K = 25 °C



CLICKER Q:

At normal pressures, solid CO_2 (dry ice) does not melt, but instead undergoes sublimation above -78.51°C.

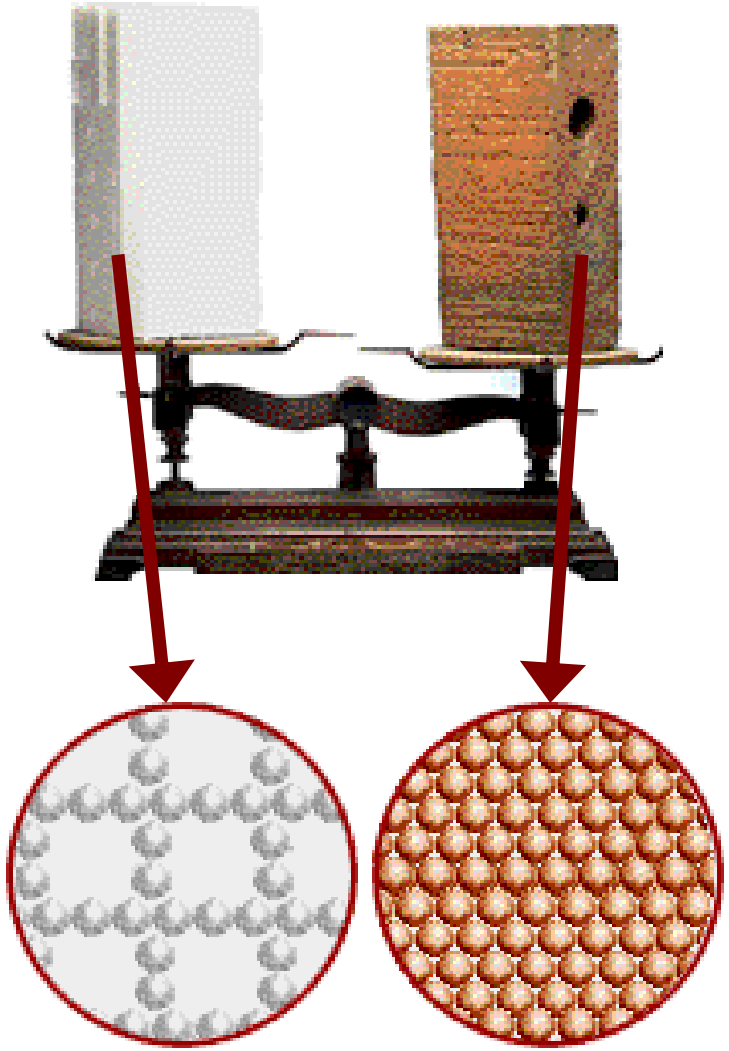
What is this temperature in Kelvins?

(33)

A. -351.66 K
B. 78.51 K
C. 194.64 K

1.6 Physical properties: DENSITY

$$d = \frac{\text{mass}}{\text{volume}}$$



How heavy is a given volume of a substance?

Depends on:

1.) mass of individual particles (atoms/ions/molecules)

2.) how tightly packed together they are in the structure

= a characteristic, *intrinsic*, physical property of any pure substance

A very useful intrinsic property:
DENSITY IS AN 'IDENTIFICATION TAG'

TABLE 1.5 Densities of Various Common Substances* at 20°C

Substance	Physical State	Density (g/cm^3)
Oxygen	Gas	0.00133
Hydrogen	Gas	0.000084
Ethanol	Liquid	0.789
Benzene	Liquid	0.880
Water	Liquid	0.9982
Magnesium	Solid	1.74
Salt (sodium chloride)	Solid	2.16
Aluminum	Solid	2.70
Iron	Solid	7.87
Copper	Solid	8.96
Silver	Solid	10.5
Lead	Solid	11.34
Mercury	Liquid	13.6
Gold	Solid	19.32

*At 1 atmosphere pressure

From Zumdahl's Chemistry, 6th Edition

Density is affected by temperature

FOR MOST SUBSTANCES: density ↑ as temperature ↓

WHY?

→ attractive forces between particles are more significant when particles' kinetic energy decreases

⇨ particles move closer together

⇨ volume decreases

Must specify temperature when discussing:

- density
- volume

Kotz 6th Fig.1.11
cf 8th Fig.1.14

$H_2O(s)$ is strange: most solids sink in their liquids

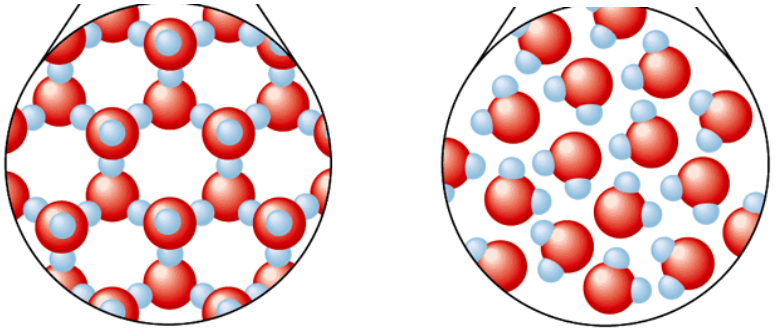
Temperature (°C)	Density of H_2O (g/mL)
0 (solid)	0.917
0 (liquid)	0.99984
2	0.99994
4	0.99997
10	0.99970
25	0.99707
100	0.95836

Ice is less dense than liquid water at same temp…

Most dense at 4°C

WHY?

When locked in ideal geometry for interaction (as in solid), H_2O molecules are a bit farther apart than in liquid!



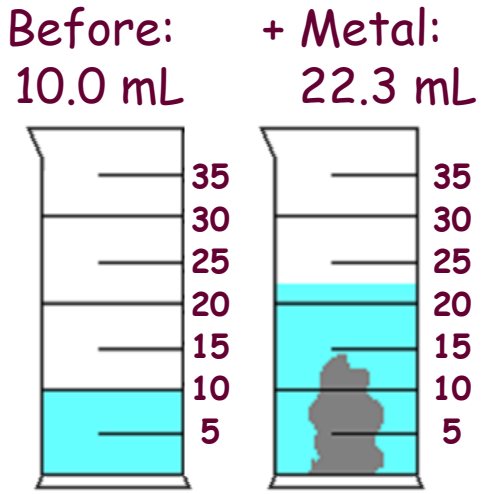
SOLID (ice) **LIQUID (water)**

From Zumdahl's *Chemistry* 6th Ed.

CLICKER Q: Determination of a metal's density

An irregularly shaped piece of metal with a mass of 33.2 g is immersed in 10.0 mL of water in a graduated cylinder (result shown).

Determine the identity of the metal.



A. Magnesium, Mg
B. Aluminum, Al
C. Iron, Fe
D. Silver, Ag
E. Lead, Pb

Density ($g \cdot cm^{-3}$)	
Mg	1.74
Al	2.70
Fe	7.87
Ag	10.5
Pb	11.3

ASSIGNED READINGS

- BEFORE NEXT CLASS:

  Read Ch. 1 (all, including "Let's review" sections)
  & work on exercises

  & learn to use your calculator properly (*e.g.*, scientific notation)

- **LABS & TUTORIALS START NEXT WEEK.**
  ARRIVE PREPARED: lab coat, safety glasses
  lab manual
  completed Expt. #1 prelab.
  completed tutorial homework

- **CHEM 101 SEMINARS NEXT WEEK.**
  SIGN UP AT CHEMISTY MAIN OFFICE: SP-201.01