General Chemistry II

Chem 102

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Chemistry New Building - 1st Floor

Ahmad Alakraa

Lecture 1

Introduction

Basic Principles of Chemistry

References

- Chemistry: An Atoms First Approach, Steven S. Zumdahl and Susan A. Zumdahl, 2012, Brooks Cole, a part of Cengage Learning.
- Chemistry: The Central Science, Theodore L. Brown et al., 2012, Pearson Prentice Hall, USA
- Chem 102 Note @ Chem. Dept.

Assessment

- 2 h unseen written examination $\Rightarrow$ 60 marks
- ~ 50 min midterm examination $\Rightarrow$ 10 marks
- Laboratory work $\Rightarrow$ 30 marks

Overall $\Rightarrow$ 100 marks

Lectures’ attendance should exceed 70 %

Content

- Introduction: Units & Dimensional Analysis
- Gases
- Liquids & Solids

  (Gases, Liquids & Solids: States of Matter)
- Thermochemistry
- Solutions
- Chemical equilibrium
- Ionic equilibrium

Introduction

- Matter & States' Conversions
- Equations & Stoichiometry
- Units
- Precision and Accuracy
- Significant Figures
- Dimensional Analysis
- Limiting Reactant

Chemistry concerns with

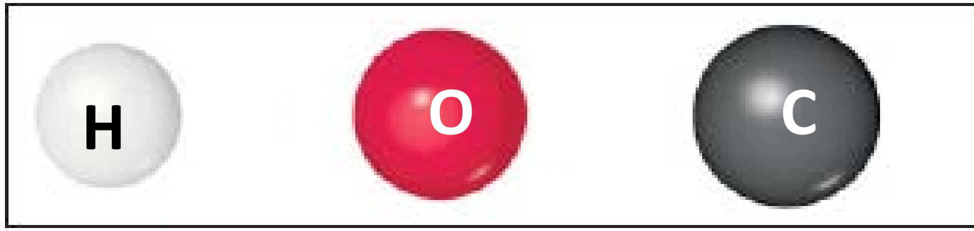
- **Synthesizing** matter or materials “anything occupying a space and has a mass”

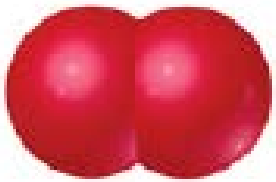
- **Evaluating** their properties (composition, structure, reactivity) ⇒ (States of matter).

- **Inspecting** their reactivity “reactions” (Thermodynamics).

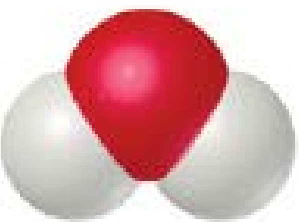
- **Estimating** (how fast) and changing reactions’ kinetics (catalysis, inhibition) .

Properties vs. Structure and Composition

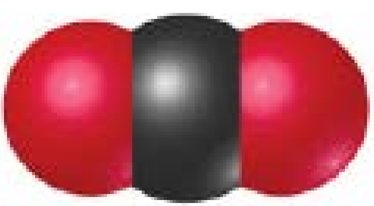




Oxygen



Water



Carbon dioxide

ethanol C_2H_6O

Ethylene Glycol $C_2H_6O_2$

Aspirin $C_9H_8O_4$

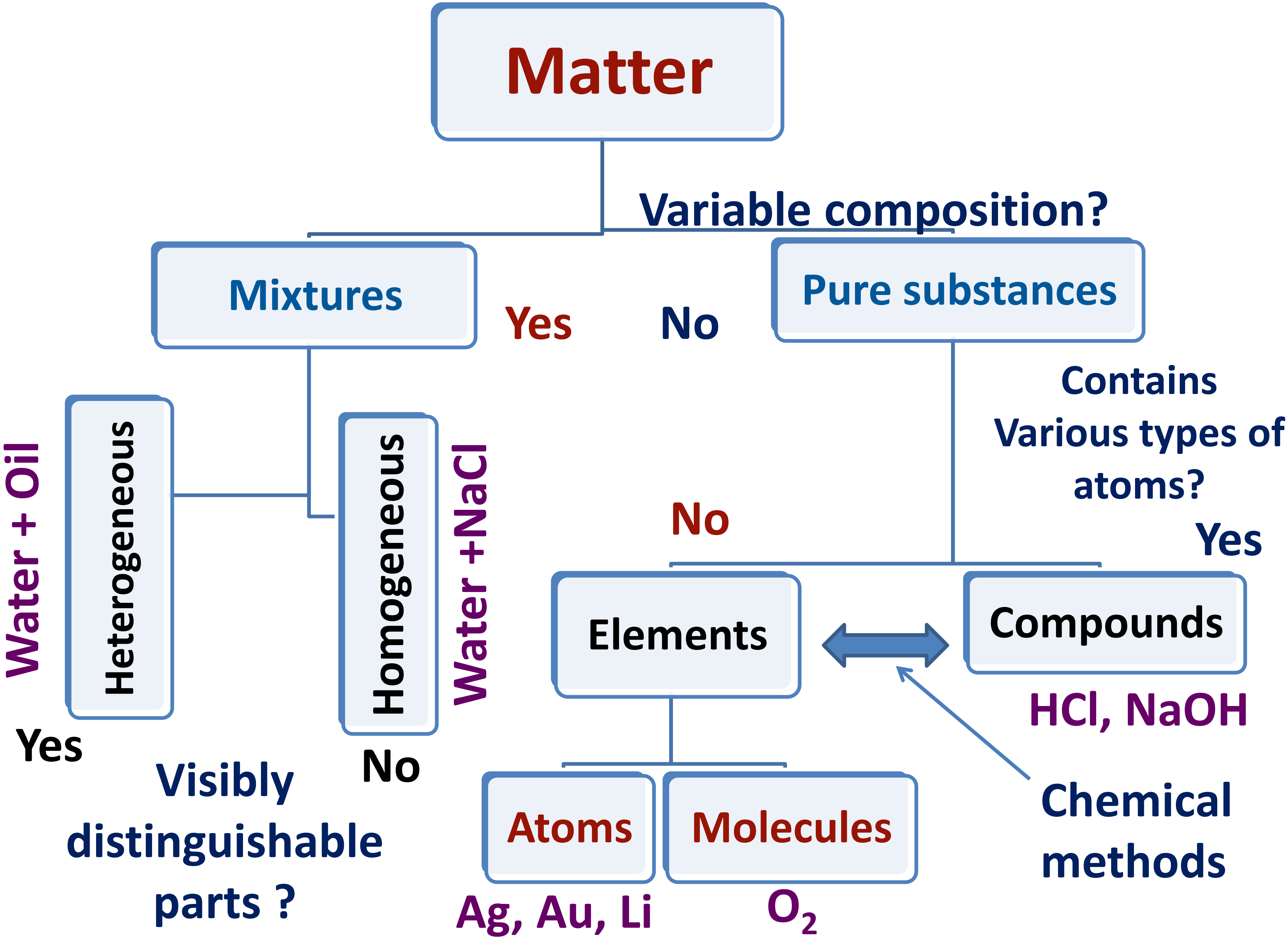

Matter
Variable composition?
Mixtures
Yes
No
Pure substances
Contains
Various types of
atoms?
Water + Oil
Heterogeneous
Homogeneous
Water +NaCl
No
Yes
Elements
Compounds
HCl, NaOH
Yes
Visibly
distinguishable
parts ?
No
Atoms
Molecules
Chemical
methods
Ag, Au, Li
O_2

TABLE R.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

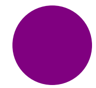
*At 1 atmosphere pressure.

Interatomic distance & Volume

Density & Intermolecular force

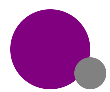
Types of motion

- **Translational**



whole atom or molecule changes its location in three dimensional space

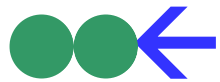
- **Rotational**



whole molecule spins around an axis in three dimensional space

Motion of whole molecule

- **Vibrational**



Motion within a molecule

motion that changes the shape of the molecule – stretching, bending, and rotation of bonds

Properties "Characteristics" of Matter

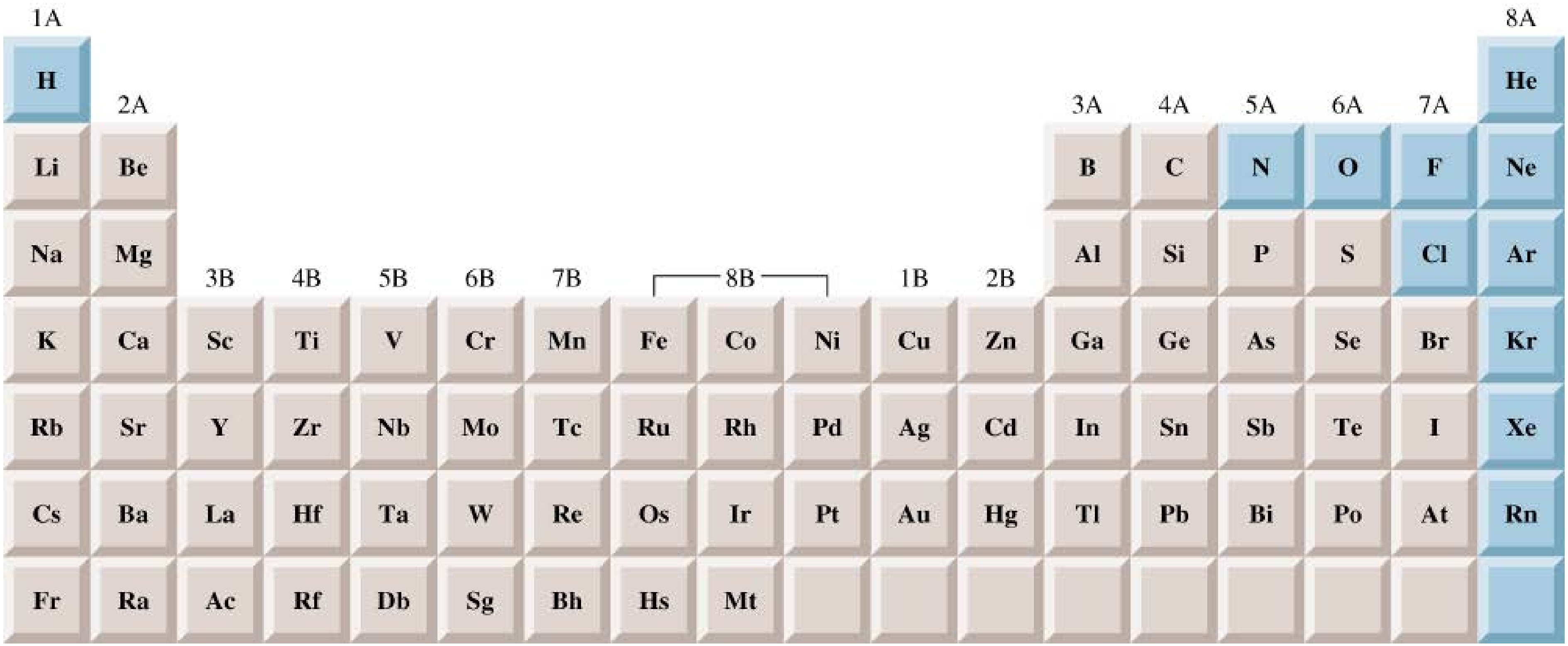
Character	Solid	Liquid	Gas
Attraction	Strong	Intermediate	Very weak
Shape	Fixed	Not fixed	Not fixed
Volume	Fixed	Fixed	Not fixed, Highly dependent of P, T
Motion (Translation, Rotational, Vibrational)	V- Only vibrating	TR - Move around past each other	TRV Freely – randomly
Compressibility	No	little	high
KE	**Lowest**	**Intermediate**	**Highest**

Liquids and Solids: **Condensed phases**

Liquids and Gases: **Fluids**

Gas	Liquid	Solid
Particles are far apart, run in rapid random motion (translation, rotational, vibrational)	Particles lies in-between, intermediate motion (translation, rotational)	Particles are very close together, vibrate only in place
High volumes and Low densities	Intermediate volumes and densities	Small volumes and high densities
Very weak attraction forces	Intermediate forces	Strong forces
assumes the shape and volume of its container	assumes the shape of the part of the container which it occupies – has a fixed volume	retains a fixed volume and shape rigid - particles locked into place
compressible lots of free space between particles	not easily compressible little free space between particles	not easily compressible little free space between particles
flows easily particles can move past one another	flows easily particles can move/slide past one another	does not flow easily rigid - particles cannot move/slide past one another

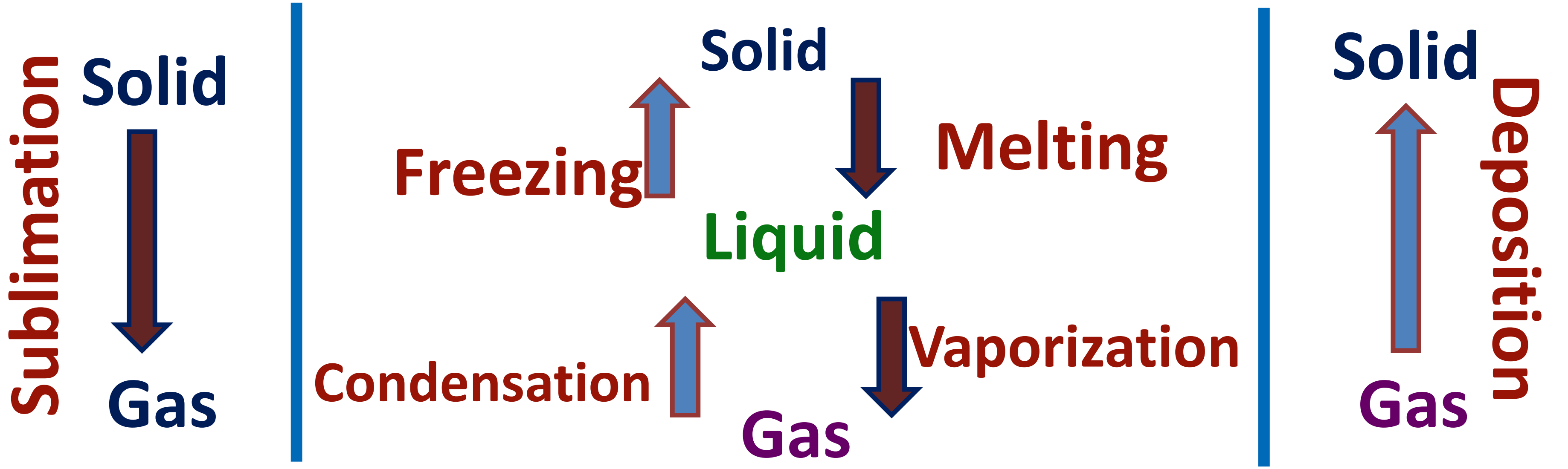
Elements that exist as gases at 25°C and 1 atm



Some Substances Found as Gases at 1 atm and 25°C

Elements	Compounds
H_2 (molecular hydrogen)	HF (hydrogen fluoride)
N_2 (molecular nitrogen)	HCl (hydrogen chloride)
O_2 (molecular oxygen)	HBr (hydrogen bromide)
O_3 (ozone)	HI (hydrogen iodide)
F_2 (molecular fluorine)	CO (carbon monoxide)
Cl_2 (molecular chlorine)	CO_2 (carbon dioxide)
He (helium)	NH_3 (ammonia)
Ne (neon)	NO (nitric oxide)
Ar (argon)	NO_2 (nitrogen dioxide)
Kr (krypton)	N_2O (nitrous oxide)
Xe (xenon)	SO_2 (sulfur dioxide)
Rn (radon)	H_2S (hydrogen sulfide)
	HCN (hydrogen cyanide)*

Conversion of States: Physical not chemical change



- Sublimation is the conversion of a state from the solid phase directly to a gas phase, without passing by the liquid state.

- Deposition is the direct conversion from the gaseous to the solid state, without passing by the liquid phase.

Boiling Point

Temperature at which the vapor pressure of the liquid equal the **external atmospheric pressure**

Normal Boiling Point

Temperature at which the vapor pressure of the liquid equal **1 atm**

Normal Melting/Freezing Point

Temperature at which the vapor pressure of a liquid **equals** the vapor pressure of its solid

Chemical Reactions/Balancing

- **Reorganization of atoms in one or more substances.**

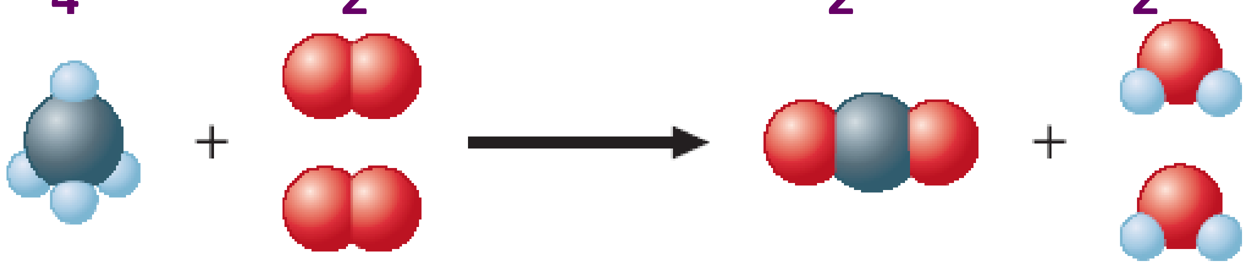
Mass is conserved in chemical reactions

$$CH_4 + O_2 \rightarrow CO_2 + H_2O$$

Unbalanced

- **Atoms are neither created nor destroyed**

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$



Balanced

Chemical equation

- gives important information:
  - ✓ Nature
  - ✓ Relative numbers
  - ✓ Physical states

} Reactants & Products

State	Symbol
Solid	**(s)**
Liquid	**(l)**
Gas	**(g)**
Dissolved in Water (aqueous)	**(aq)**

$$HCl\ (aq) + NaHCO_3\ (s) \rightarrow CO_2\ (g) + H_2O\ (l) + NaCl\ (aq)$$

Reading Chemical Equations

	Reactants				Products		
	$CH_4(g)$	+	$2O_2(g)$	$\rightarrow$	$CO_2(g)$	+	$2H_2O(g)$
Molecules	1		2		1		2
Moles	1		2		1		2
Molecules	6.022×10^{23}		$2\,(6.022 \times 10^{23})$		6.022×10^{23}		$2\,(6.022 \times 10^{23})$
g	16		2 (32)		44		2 (18)
Total mass	80				80		

Mass is conserved in a chemical reaction

Stoichiometric Calculations

Reaction of propane with oxygen: (Combustion)

What mass of oxygen will react with 96.1 g of propane?

Balance equation

$$C_3H_8\ (g) + 5O_2\ (g) \rightarrow 3CO_2\ (g) + 4H_2O\ (g)$$

Convert masses to moles:

$$96.1\ \text{g}\ C_3H_8 \times \frac{1\ \text{mol}\ C_3H_8}{44.1\ \text{g}\ C_3H_8} = 2.18\ \text{mol}\ C_3H_8$$

- Number of moles of O_2 necessary to react with 2.18 mole C_3H_8

$$2.18 \text{ mol } C_3H_8 \times \frac{5 \text{ mol } O_2}{1 \text{ mol } C_3H_8} = 10.9 \text{ mol } O_2$$

- **Convert** from moles to grams O_2

$$10.9 \text{ mol } O_2 \times \frac{32 \text{ g } O_2}{1 \text{ mol } O_2} = 349 \text{ g } O_2$$

- Therefore, 349 g O_2 is required to burn 96.1 g propane.

- What mass of carbon dioxide is produced when 96.1 grams of propane is combusted with oxygen? (Homework)

Units of measurements

SI system

French Système International d'Unités.

7 SI Base UNITS

from which all other units are derived

Dimension	Unit	Unit Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Temperature	kelvin	K
Electrical Current	ampere	A
Amount of light	candela	cd
Amount of matter	mole	mol

Recognize the capital and small letters

Standard prefixes in SI Base units

Multiple	Prefix
10^{24}	yotta, Y
10^{21}	zetta, Z
10^{18}	exa, E
10^{15}	peta, P
10^{12}	tera, T
10^{9}	giga, G
10^{6}	mega, M
10^{3}	kilo, k
10^{2}	hecto, h
10^{1}	deka, da
10^{-1}	deci, d
10^{-2}	centi, c
10^{-3}	milli, m
10^{-6}	micro, μ
10^{-9}	nano, n
10^{-12}	pico, p
10^{-15}	femto, f
10^{-18}	atto, a
10^{-21}	zepto, z
10^{-24}	yocto, y

Exercises

- Which is the smallest: 1 mg, 1 μg, or 1 pg? 1 pg
- What is the name of the unit that equals to (a) 10^{-9} g , (b) 10^{-6} s, (c) 10^{-3} m? ng, μs, mm
- How many picometers are there in 1 m? 10^{12} pm
- Express 6.0×10^{3} m using a prefix to replace the power of ten? 6.0 km
- Use exponential notation to express 4.22 mg in grams? 4.22×10^{-3} g
- Use decimal notation to express 4.22 mg in grams?

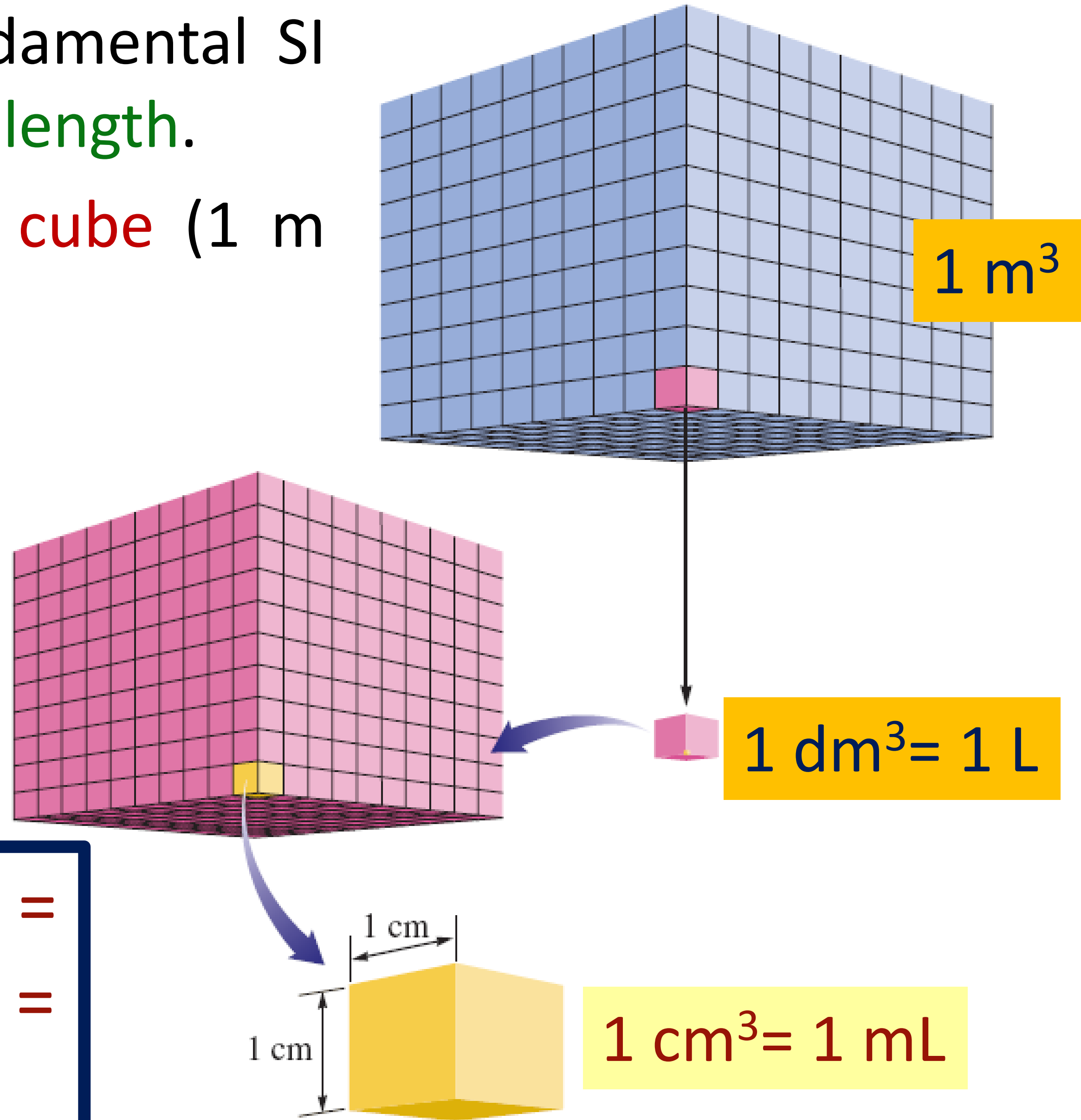
  0.00422 g

Derived SI Units

- **Volume** is not a fundamental SI unit but derived from length.
- The volume (V) of a cube (1 m edge) = $(1\ m)^3 = 1\ m^3$.

$1\ m^3 = 1000\ dm^3$

$1\ dm^3 = 1000\ cm^3$



$$1L = (1\ dm)^3 = 1\ dm^3 = (10\ cm)^3 = 1000\ cm^3 = 1000\ mL = 1L$$

Other Derived SI Units

Physical quantity	Symbol (s)	Name of SI unit	Derived Unit	Definition
Frequency	v, f	Hertz	Hz	s^{-1}
Force	F	Newton	N	$kg\ m\ s^{-2} = J\ m^{-1}$
Energy	E, H,V, etc	Joule	J	$N\ m = kg\ m^{2}\ s^{-2}$
Pressure	P	Pascal	Pa	$N\ m^{-2} = kg\ m^{-1}s^{-2}$
Power	p	Watt	W	$J\ s^{-1} = kg\ m^{2}\ s^{-3}$
Charge	Q	Coulomb	C	A s
Potential	E,...etc	Volt	V	$J\ A\ s^{-1}$
Resistance	R	Ohm	Ω	$V\ A^{-1}$
Conductance	G	Siemens	S	Ω^{-1}
Capacitance	C	Farad	F	$C\ V^{-1}$

Other Units

Physical quantity	Symbol	SI unit
Area	A	m^2
Volume	V	m^3
Velocity	U, V, c	$m\ s^{-1}$
Acceleration	a, g	$m\ s^{-2}$
Weight	G,W	N
Density	p	$kg\ m^{-3}$
Volume	liter (l)	dm^3
Force	dyne (dyn)	10^{-5} N
Concentration	Molar (M)	$mol\ dm^{-3}$
Energy	Calorie (Cal)	4.18 J
Energy	Erg (erg)	10^{-7} J
Pressure	Atmosphere (atm)	1.013×10^5 Pa
Pressure	(mm Hg)	133.322 Pa
Pressure	Torr (torr)	133.322 Pa
Pressure	Bar	10^5 Pa
Pressure	Atmosphere	760 mm Hg = 76 cm Hg

Temperature

- is a physical property for the **hotness** or **coldness** of an object. It determines "direction of heat flow".
- **Heat** always flows **spontaneously** from a substance of a **higher T** to another of a **lower T**.
- The T scales are commonly **Celsius** and **Kelvin**.
- The **Celsius scale** is based on the assignment of **0 °C** to the freezing point of water and **100 °C** to its boiling point at sea level.
- The SI unit of temperature is the **Kelvin (K)**.

- Zero on the Kelvin scale is the lowest attainable temperature, –273.15 °C, referred to as absolute zero (Temperature at which the gas molecules stop to move)

- The Celsius and Kelvin scales have equal-sized units.

$$T(K) = T(°C) + 273.15$$

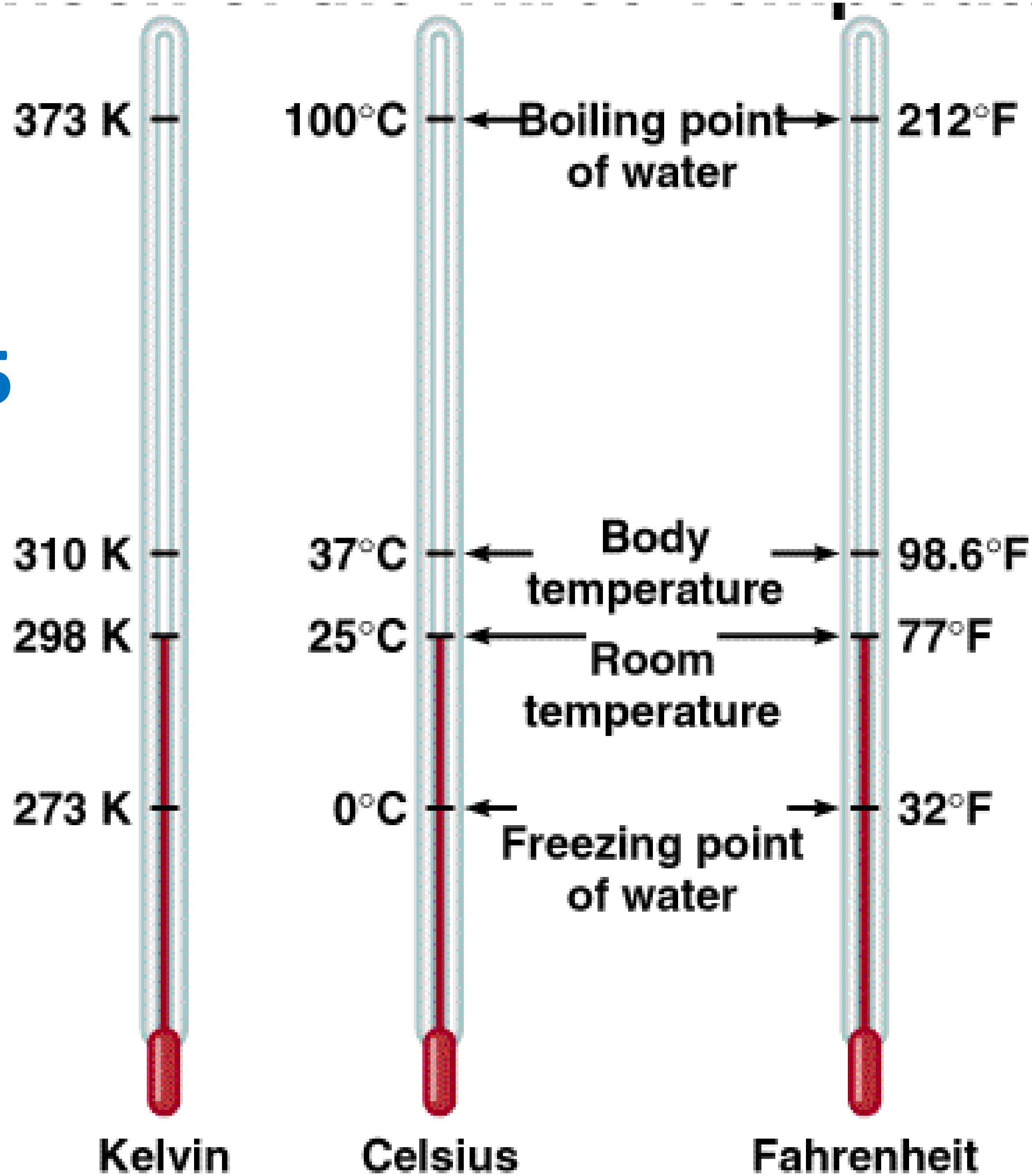
- The common temperature scale in the United States is the Fahrenheit scale.

Water freezes at 32 °F and boils at 212 °F

$$^{o}F = \frac{9}{5}(\,^{o}C) + 32$$

Scales comparison

K = °C + 273.15



$$^{o}C = \frac{5}{9}(\,^{o}F - 32)$$

Exercises

- Normal body temperature is 98.6°F. Convert this temperature to the Celsius and Kelvin scales?

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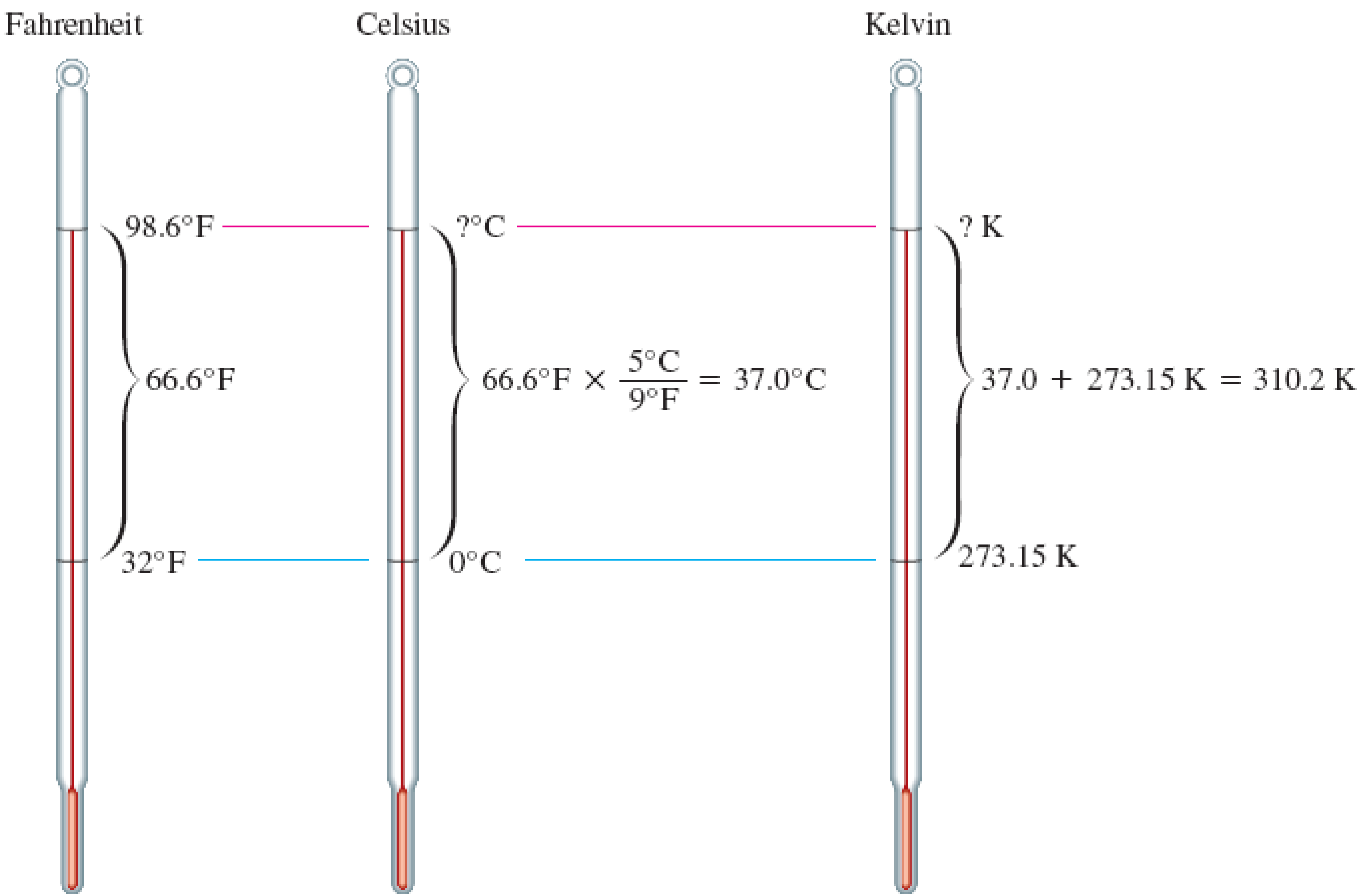
$$^{o}C = \frac{5}{9}(98.6 - 32.0) = 37.0\ ^{o}C$$

- **Convert to the Kelvin scale:**

$$\mathrm{T} = 37.0\ ^{o}\mathrm{C} + 273.15 = 310.2\ \mathrm{K}$$

- Note that the final answer has only one decimal place (37.0 is limiting)



Fahrenheit
Celsius
Kelvin
98.6°F
?°C
? K
66.6°F
66.6°F × 5°C / 9°F = 37.0°C
37.0 + 273.15 K = 310.2 K
32°F
0°C
273.15 K

Exercise

One interesting feature of the Celsius and Fahrenheit scales is that –40°C and –40°F represent the same temperature. Verify this information?

==

- The difference between 32°F and – 40°F is 72°F. The difference between 0°C and – 40°C is 40°C. The ratio of these is

$$ {}^{o}F = \frac{9}{5}({}^{o}C) + 32 $$

$$ \frac{72\ {}^{o}\mathrm{F}}{40\ {}^{o}\mathrm{C}} = \frac{8\ \times\ 9\ {}^{o}\mathrm{F}}{8\ \times\ 5\ {}^{o}\mathrm{C}} = \frac{9\ {}^{o}\mathrm{F}}{5\ {}^{o}\mathrm{C}} $$

Thus – 40°C is equivalent to – 40°F.

Pressure

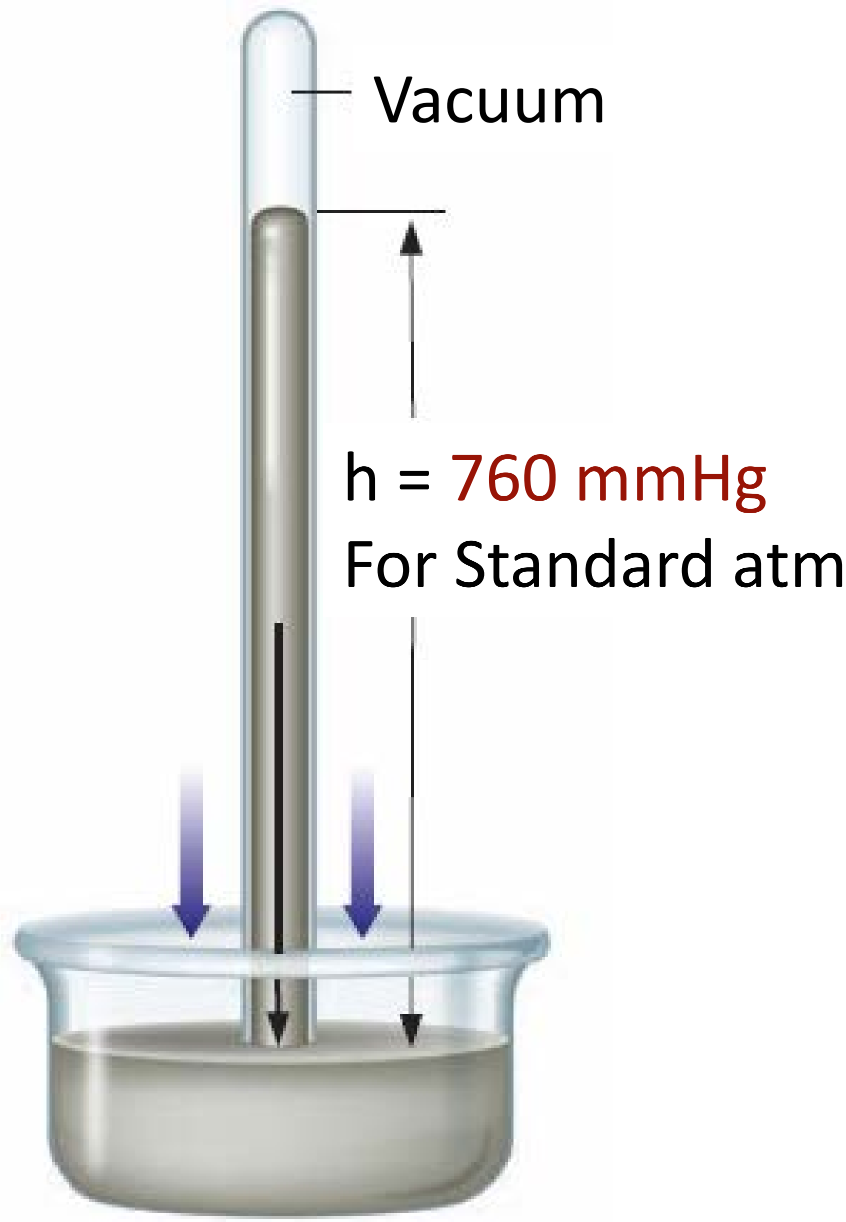
- is the normal force exerted by a fluid (gas or liquid) per unit area.
- It has the unit (N/m^2), which is called a Pascal (Pa).
- Pressure is also used on solid surfaces as synonymous to normal stress.

$$1 \text{ bar} = 10^5 \text{ Pa} = 0.1 \text{ MPa} = 100 \text{ kPa}$$

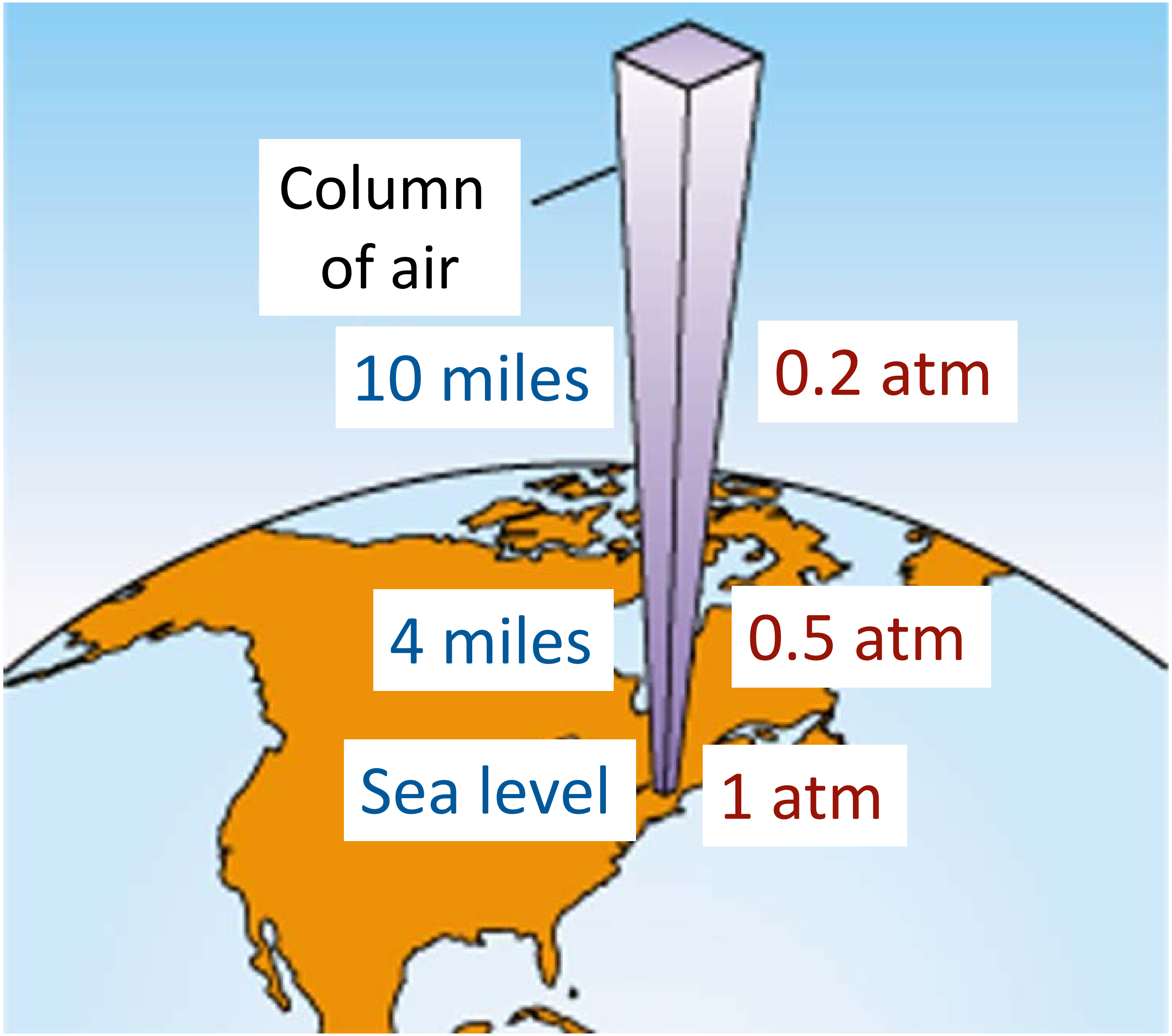
$$1 \text{ atm} = 101{,}325 \text{ Pa} = 101.325 \text{ kPa} = 1.01325 \text{ bars} = 760 \text{ mm Hg} = 760 \text{ torr}$$

Measuring P: Torricelli's barometer 1643

- Gases mix completely and exert pressure on surroundings.
- Torricelli's barometer is constructed by filling a glass tube with liquid mercury and inverting it in a dish of mercury.
- At sea level the height of this column of mercury averages 760 mm.



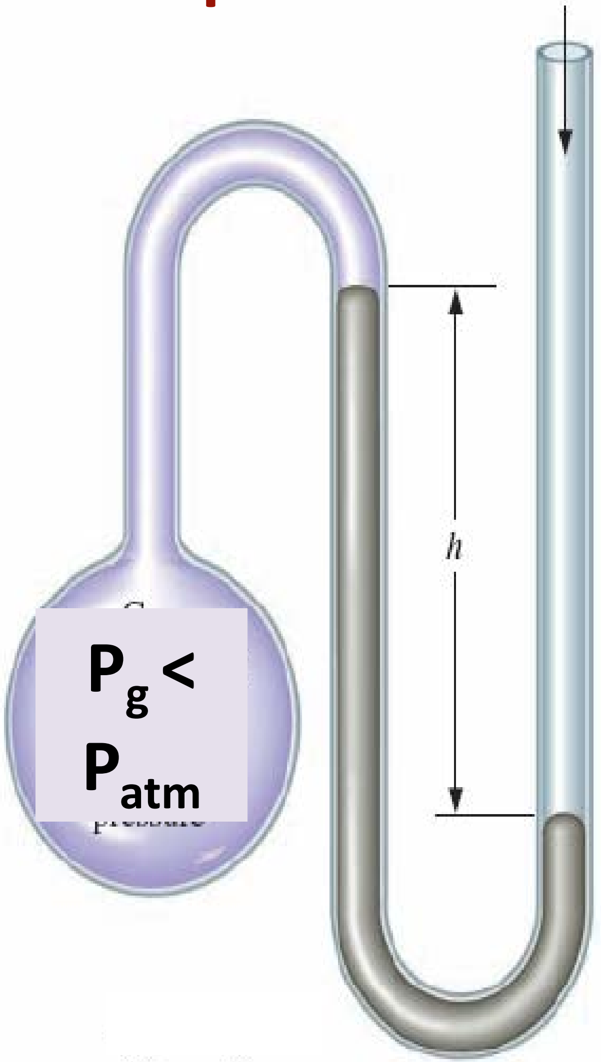
▶ Pressure decreases at higher altitudes

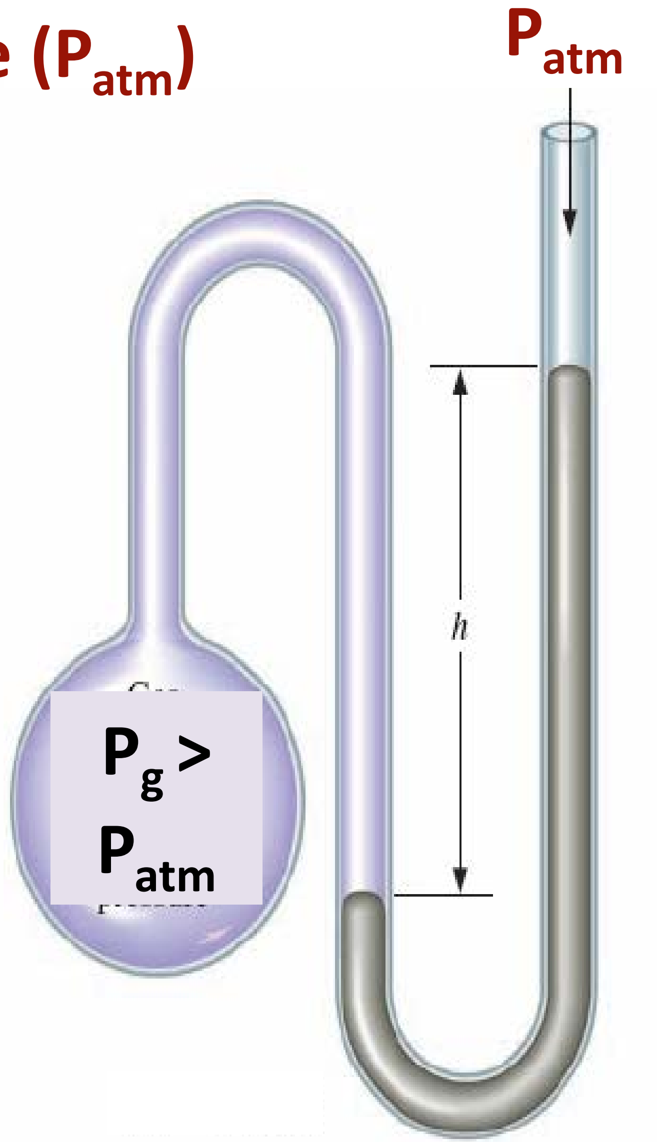


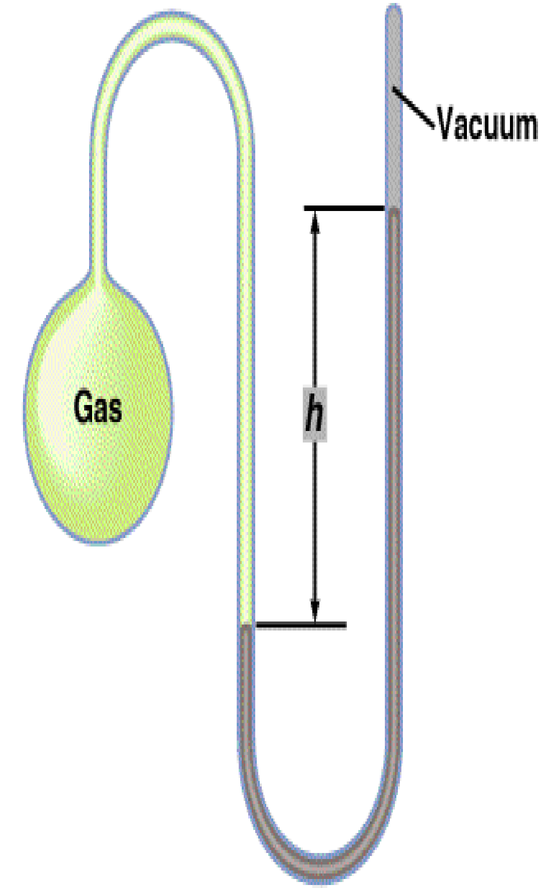
Manometers

$P_h = \rho g h$

Atmospheric Pressure (P_{atm})







$P_{gas} = P_{atm} - P_h$

$P_{gas} = P_{atm} + P_h$

$P_{gas} = P_h$

- In CGS system, P is measured in dyne cm^{-2}
- The standard atmosphere is the pressure exerted by a 76 cm high column of mercury of density 13.6 g cm^{-3} in a place where the acceleration due to gravity is 980 cm s^{-2}).

$$P\ (\text{atm}) = \frac{\text{Force}}{\text{Area}} = \frac{\text{Mass} \times \text{Acceleration}}{\text{Area}}$$

$$= \frac{\text{Volume} \times \text{density} \times \text{Acceleration}}{\text{Area}}$$

$$= \text{Length} \times \text{density} \times \text{Acceleration}$$

$$76\ \text{cm} \times 13.6\ \text{g cm}^{-3} \times 980\ \text{cm s}^{-2}$$

$$1.01325\ \times 10^{6}\ \text{g cm}^{-1}\text{s}^{-2}\ (\text{dyne cm}^{-2})$$

SI system

P is measured in $N\ m^{-2}$ (Pa: Pascal)

$$P\ (atm) == Length \times density \times Acceleration$$

$$0.76\ m \times 1.36 \times 10^{4}\ kg\ m^{-3} \times 9.8\ m\ s^{-2}$$

$$1.01325\ \times 10^{5}\ kg\ m^{-1} s^{-2}\ (N\ m^{-2})(Pa)$$

1 atm = 1.0325 bar = 760 mmHg

= 760 torr = 101,325 N/m^2 = 101,325 Pa