بسم الله الرحمن الرحيم

Chapter 1

Introduction to Gases and Thermodynamics

https://sites.google.com/site/chemstoked/home/apchem/ap-unit-resources/3-thermochemistry-gas-laws

العلم الذي يتعامل مع الشروط الخاصه ب ماده او مجموعه مواد
والعوامل العكسية التي تنتج مادة اخرى

Chemistry is the science which treats of the conditions under which one substance of itself, or several substances by reciprocal action, give rise to the appearance of new substances. The province of chemistry also includes the description of the substances, as well as of the phenomena which accompany the formation of new substances.

يشتمل ايضاً وصف للمواد و العرضيات حول تحول
مادة الى اخرى

دراسة نظرية كمية حول خصائص وتركيب المادة وعلاقتها بالطاقة

Physical Chemistry: Quantitative and theoretical study of the properties and structure of matter and their relation to the interaction of matter and energy.

This course serves also as an introduction to **chemical thermodynamics**, giving you an understanding of basic principles, laws, and theories of physical chemistry that are necessary for chemistry, biochemistry, pre-medical, general science, and engineering students.

ديناميكا حرارية كيميائية

By performing well in this course you should:

- gain abilities in quantitative problem solving
- develop the ability to use original thought (and logic) in the solution of problems and the derivation of equations.

What about the mathematics ?

- Equations should not obfuscate the science !
- ***Mathematics should paint a clear picture of the physical phenomena being studied.***

Course Outline

1 - The properties of gases

- The kinetic theory of gases

2 - The Laws of Thermodynamics

3 - Physical transformations of pure substances

4 - Simple mixtures

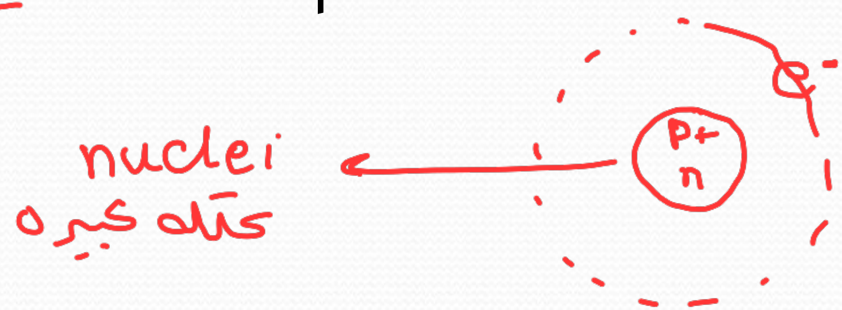
Matter

We define matter as anything that has mass and takes up space.

Composed of electrons and nuclei (neutrons and protons) which can be further divided (but not here) into subatomic particles.

Matter has the following physical properties:

- Mass -largely due to nuclei
- Electronic moments -monopole (charge) is most important
- Magnetic moments -dipole is most important



Quantification of Matter

Substance: a pure form of matter

Amount of substance (n): reported in terms of moles. 1 mol of a substance contains as many entities as exactly 12 g of carbon-12 (around 6.02×10^{23} entities).

Avogadro's number: $N_A = 6.0221 \times 10^{23} mol^{-1}$

Extensive property: dependent upon the amount of matter in the substance (e.g. mass, volume)

Intensive property: independent upon the amount of matter in the substance (e.g. density, pressure, temperature)

SI Units

النظام العالمي للمقاييس

	Physical Quantity	Name of Unit	Abbreviation
كتلة	Mass	Kilogram	kg
طول	Length	Meter	m
زمن	Time	Second	s[a]
درجة الحرارة	Temperature	Kelvin	K
كمية المادة	Amount of substance	Mole	mol
تيار كهربائي	Electric current	Ampere	A
شدة الإضاءة	Luminous intensity	Candela	cd

[a]The abbreviation sec is frequently used.

Metric System

Prefixes convert the base units into units that are appropriate for the item being measured.

Prefix	Abbreviation	Meaning	Example
Giga	G	10^{9}	1 gigameter (Gm) = 1×10^{9} m
Mega	M	10^{6}	1 megameter (Mm) = 1×10^{6} m
Kilo	k	10^{3}	1 kilometer (km) = 1×10^{3} m
Deci	d	10^{-1}	1 decimeter (dm) = 0.1 m
Centi	c	10^{-2}	1 centimeter (cm) = 0.01 m
Milli	m	10^{-3}	1 millimeter (mm) = 0.001 m
Micro	μ[a]	10^{-6}	1 micrometer (μm) = 1×10^{-6} m
Nano	n	10^{-9}	1 nanometer (nm) = 1×10^{-9} m
Pico	p	10^{-12}	1 picometer (pm) = 1×10^{-12} m
Femto	f	10^{-15}	1 femtometer (fm) = 1×10^{-15} m

[a]This is the Greek letter mu (pronounced "mew").

What is the name given to the unit that equals **(a)** 10^{-9} gram, **(b)** 10^{-6} second, **(c)** 10^{-3} meter?

SI Derived Units

Derived quantity	Name	Symbol
Volume	cubic meter	m^3
Speed (velocity)	meter per second	m/s or $m\ s^{-1}$
Acceleration	meter per second squared	m/s^2 or $m\ s^{-2}$
Wave number	reciprocal meter	m^{-1}
Mass density	kg per cubic meter	kg/m^3 or $kg\ m^{-3}$
Frequency	hertz	Hz: s^{-1}
Force	newton	N: $kg\ m\ s^{-2}$
Pressure, stress	pascal	Pa: N/m^2: $kg\ m^{-1}\ s^{-2}$
Energy,work, heat	joule	J: N m: $kg\ m^2\ s^{-2}$
Power	watt	W: J/s: $kg\ m^2\ s^{-3}$
Electric charge	coulomb	C: A s
Electric potential	volt	V: W/A: $kg\ m^2\ s^{-3}\ A^{-1}$

Thermodynamics

Thermodynamics:

Thermodynamics deals with energy changes accompanying physical and chemical transformations.

Thermodynamics is the science of the flow of heat (energy). So, thermo is heat, and dynamics is the motion of heat.

- Describes macroscopic properties of equilibrium systems
- Entirely Empirical
- Built on 4 Laws and “simple” mathematics

It was developed before people knew about atoms and molecules. So it's a science that's based on macroscopic properties of matter. Since then, since we know about atoms and molecules now, we can rationalize the concepts of thermodynamics using microscopic properties

الخصائص الجاهرية

الخصائص المجهرية

In thermodynamics, the laws of thermodynamics define the rules of temperature equivalence (zero'th law), energy conservation (first law), entropy tendencies (second law), and conditions for an absence of temperature (third law). The combined law of thermodynamics, sometimes called the Gibbs fundamental equation, is the combination of the four laws in one expression.

ملخص قوانين الديناميكا الحرارية

0th Law ⇒ Defines Temperature (T)

1st Law ⇒ Defines Energy (U)

2nd Law ⇒ Defines Entropy (S)

3rd Law ⇒ Gives Numerical Value to Entropy

These laws are UNIVERSALLY VALID, they cannot be circumvented (avoid)

خصائص الغاز

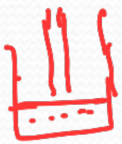
Characteristics of Gases

- Unlike liquids and solids, gases
  - expand to fill their containers;

    تتمدد حتى تملأ الوعاء
  - are highly compressible;

    لديها قابلية عالية للانضغاط
  - have extremely low densities.

    لديه كثافة منخفضة جداً



Pressure

- Pressure is the amount of force applied to an area.

$$P = \frac{F}{A}$$

$$P = \frac{(N)}{(m^2)} = N/m^2 = Nm^{-2} = \text{pascal}$$

- Atmospheric pressure is the weight of air per unit of area.

وحدات قياس الضغط

Units of Pressure

1 Pascal = 1N/m²

1 Bar = 10⁵ Pa
= 100 kPa

- **Pascals**
  - 1 Pa = 1 N/m^2
- **Bar**
  - 1 bar = 10^5 Pa = 100 kPa
- **Atmosphere**
  - 1.00 atm = 760 torr =760 mmHg
- **mm Hg or torr**
  - These units are literally the difference in the heights measured in mm (*h*) of two connected columns of mercury.

1 atm = 760 mm Hg

1 ضغط جوي = 760 mm زئبق

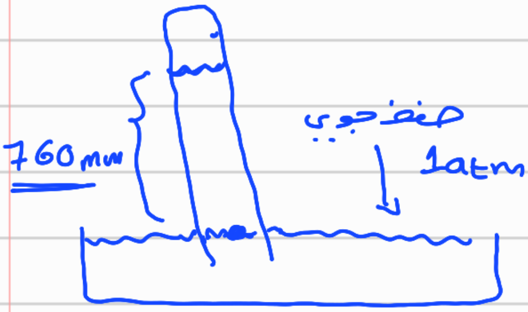
1 mmHg = 1 torr

torr او mmHg

تمثل الاختلافات h في الارتفاع بين الانابيب الموصوله ببعض المحتويه على زئبق

(1) الضغط الجوي

1 atm

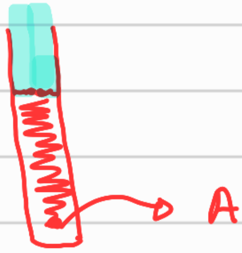


760 mm Hg

760 torr

1 atm = 760 mmHg

$P = \frac{F}{A}$



P_A = ضغط جوي + ضغط سائل

$P_{سائل} = \rho g h$

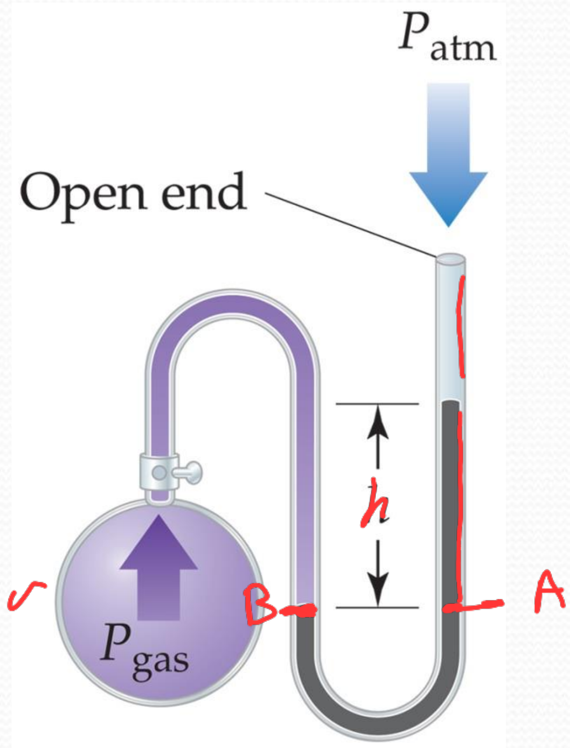
ρ : كثافة سائل

g : تسارع الجاذبية 9.8

h : ارتفاع السائل

Manometer

مانومتر



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

اداه

This device is used to measure the difference in pressure between atmospheric pressure and that of a gas in a vessel.

المانومتر هو جهاز يستخدم لقياس فرق الضغط بين الضغط الجوي و ضغط الغاز داخل وعاء

$P_A = P_B$

P_B = ضغط الغاز

P_A = ضغط الهواء + ضغط السائل

ضغط الغاز المحصور = ضغط الهواء + ضغط h

الضغط المعياري

Standard Pressure

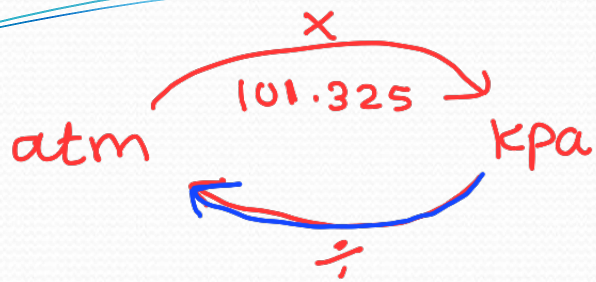
- Normal atmospheric pressure at sea level is referred to as standard pressure.

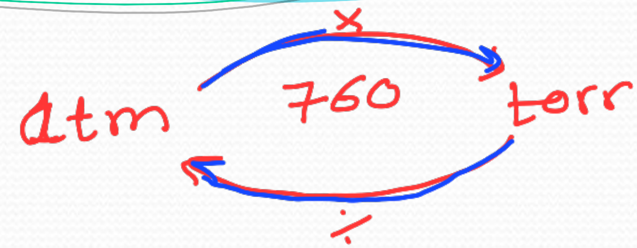
الضغط المعياري هو ضغط الهواء عند مستوى سطح البحر

- It is equal to
  - 1.00 atm
  - 760 torr (760 mm Hg)
  - 101.325 kPa

$1\ atm = 760\ mmHg$ [torr]

$1\ atm = 101325\ Pa = 101.325\ kPa$





(a)Convert 0.357 atm to torr.

$0.357 \times 760 = 271.32$ torr mmHg

(b) Convert 6.6×10^{-2} torr to atm.

$6.6 \times 10^{-2} \div 760 = 0.0000868$

8.68×10^{-5}

(c) Convert 147.2 kPa to mmHg.

$147.2 \div 101.325 \times 760$

$= 1104$ trorr

Answer

a):0.357x 760= 271.3 torr

b): 6.6 $x10^{-2}$/760= 8.6x 10^{-5} atm

c):1104 mmHg

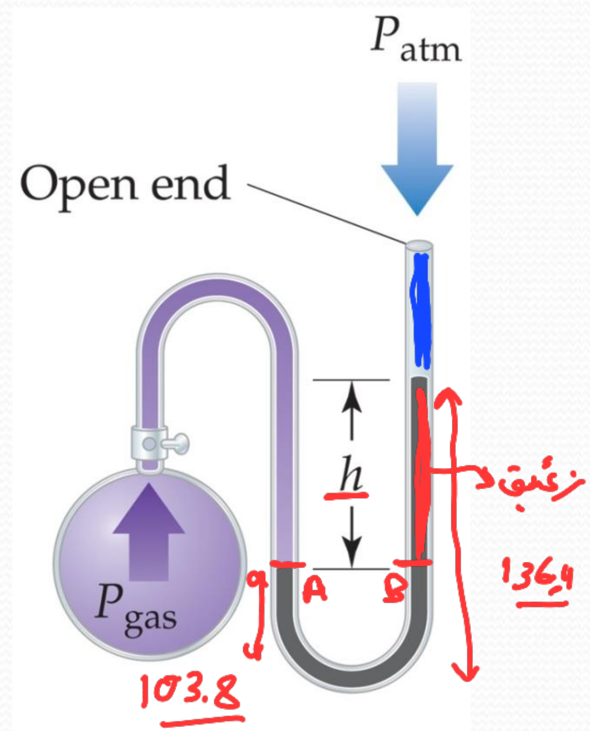
$$\frac{764.7}{760} \times 101.325 = 101.95 \text{ kPa} = 101.95\times10^{3} \text{ Pa}$$

The atmospheric pressure is 764.7 torr. A sample of gas is placed in a flask attached to an open-end mercury manometer. The level of mercury in the open-end arm of the manometer has a height of 136.4 mm, and the mercury in the arm that is in contact with the gas has a height of 103.8 mm.

What is the pressure of the gas

(a) in atmospheres,

(b) in kPa?



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

$P_A = P_B$

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

$P_{gas} = 101.95\times10^{3} + \rho g h$

$\rho g h$: 13560 kg/m^2

$h = 136.4 - 103.8 = 32.6$ mm

$P_{gass} = 101.95\times10^{3} + 13560 \times 9.8 \times 32\times10^{-3}$

$= 105252.4 \approx 105$ kPa

105 kPa → atm

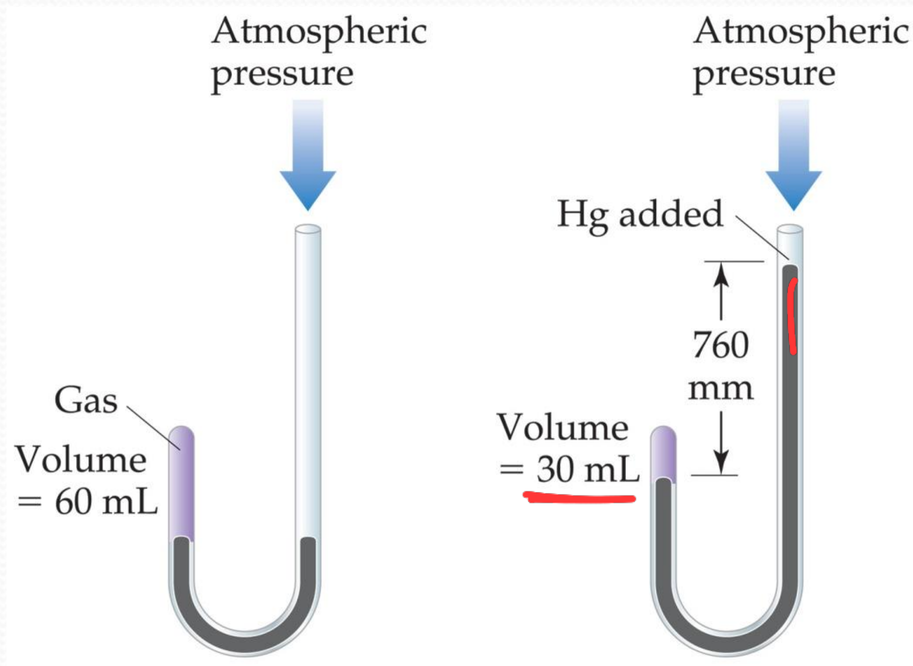
$\frac{105}{101.325} = 1.03$ atm

Boyle's Law

قانون بويل

The volume of a fixed quantity of gas at constant temperature is inversely proportional to the pressure.

بثبوت درجه الحراره فان الحجم يتناسب عكسيا مع الضغط



القوانين العامة للغازات

P :- الضغط — Pressure (atm, pa)

V :- الحجم — Volume (m^3, L, cm^3, mL)

T :- درجة الحرارة — يجب أن نستخدم (K)

n : عدد المولات — $n = \frac{m}{M}$

state 1 — P_1, V_1, T_1

stat 2 — P_2, V_2, T_2

Combined law

القانون العام للغاز

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

ثبوت الحجم

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

قانون غاي لوساك

Gay-Lussac's law

T_1, P_1 — T_2, P_2

$\frac{P}{T} = k$

علاقة طردية تبين الضغط ودرجة الحرارة

بثبوت الضغط

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

قانون شارل

Charles's law

$V_1\ T_1$ — $V_2\ T_2$

$\frac{V}{T} = k$

علاقة طردية بين V و T

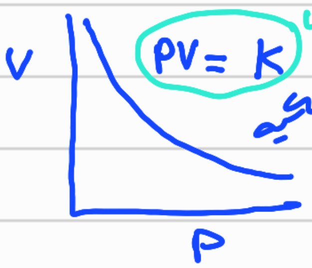
بثبوت درجة الحرارة

$$P_1 V_1 = P_2 V_2$$

بويل

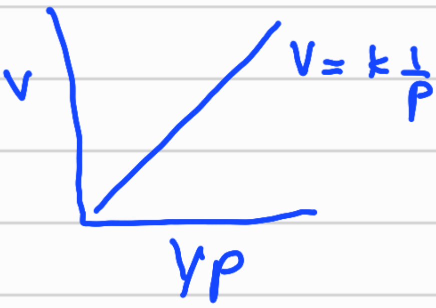
Boyles law

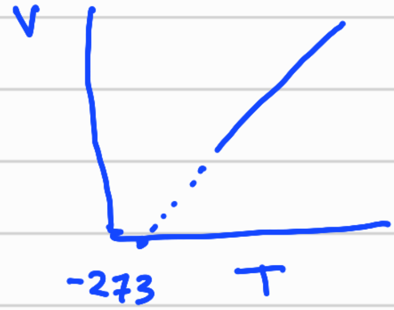
P_1, V_1 — P_2, V_2

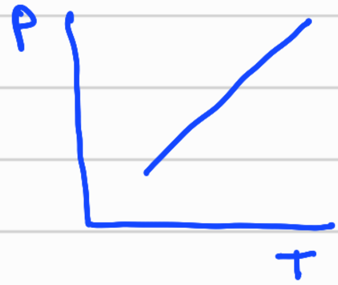


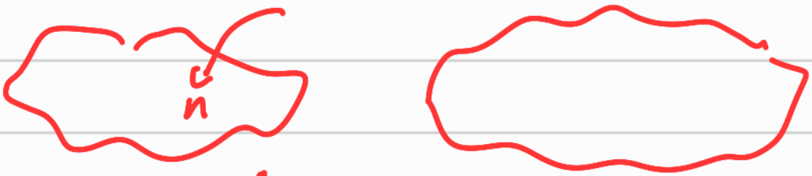
$PV = k$

علاقة عكسية بين P و V









state 1

V_1 , n_1

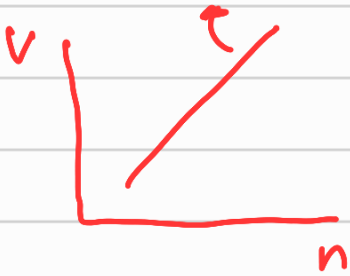
V_2 , n_2

عند زيادة عدد المولات سوف يزداد الحجم

قانون افوجادرو

Avogadro's law

$V = kn$



$$\frac{V_1}{n_1} = \frac{V_2}{n_2}$$

$$\frac{V}{n} = k$$

V, T, P, n

قانون الغاز المثالي

$$PV = nRT$$

- P: ضغط (atm)
- V: حجم (L)
- n: عدد المولات
- R: ثابت الغاز المثالي 0.0826 L atm/mol K
- T: درجة كلفن (K)

لحساب كثافة الغاز من خلال قانون الغاز المثالي

$n = \frac{m}{\mu}$

$$PV = nRT$$

$$PV = \frac{m}{\mu} RT$$

$d = \frac{m}{V}$

$$\frac{\mu PV}{RT} = m \frac{RT}{RT}$$

$$m = \frac{\mu PV}{RT}$$

كثافة ←

$$\frac{m}{V} = \frac{\mu P}{RT}$$

قانون مشتق من قانون الغاز المثالي

$$d = \frac{\mu P}{RT}$$

μ: الكتلة المولية

R: ثابت الغاز

T: درجة الحرارة

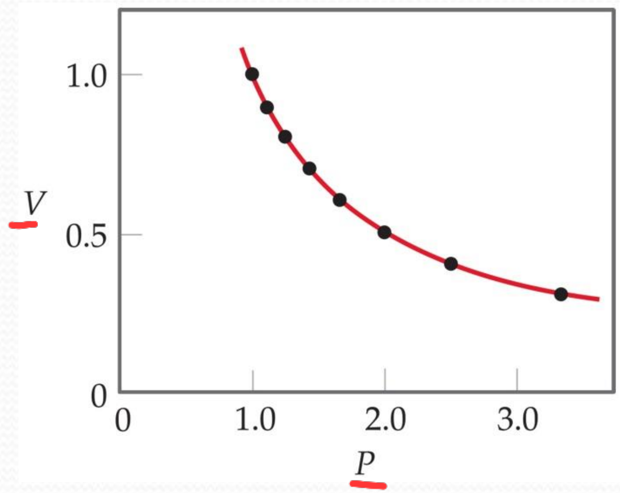
P = ضغط

d : كثافة

kg/m³ kg/L

As *P* and *V* are inversely proportional

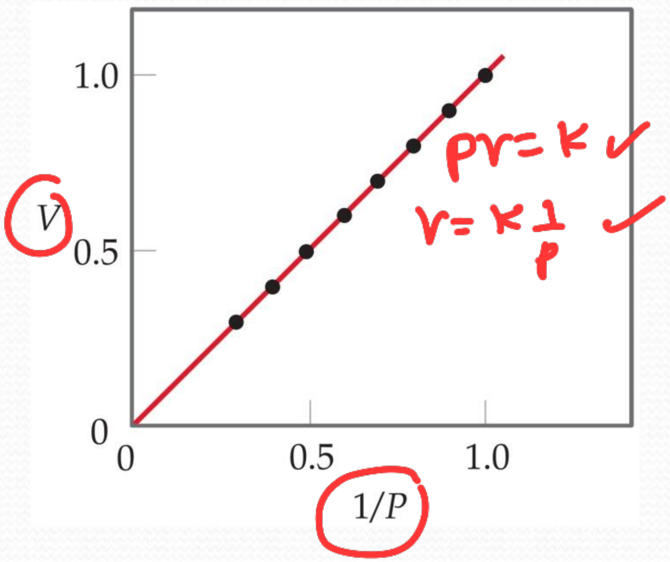
A plot of *V* versus *P* results in a curve.



Since $PV = k$

$V = k(1/P)$

This means a plot of *V* versus $1/P$ will be a straight line.

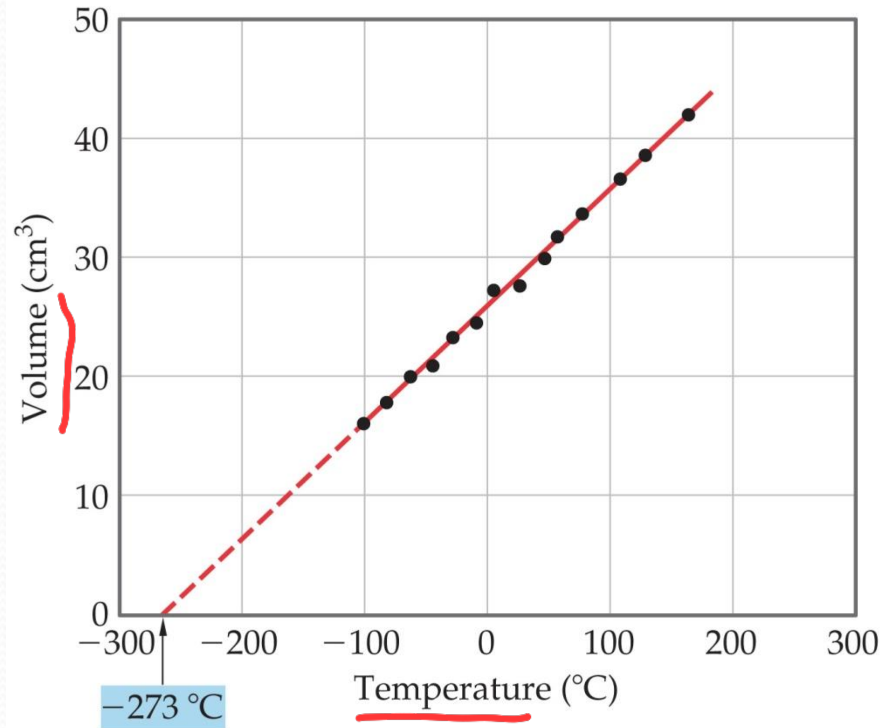


- $P_1V_1 = P_2V_2$

Charles's Law

بثبوت الضغط فان حجم الغاز يتناسب طردياً مع درجة حرارته المطلقة

- The volume of a fixed amount of gas at constant pressure is طردي directly proportional to its absolute temperature.



- i.e., $$\frac{V}{T} = k$$

A plot of *V* versus *T* will be a straight line.

- $V_1 / T_1 = V_2 / T_2$

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

Avogadro's Law

- The volume of a gas at constant temperature and pressure is directly proportional to the number of moles of the gas.

حجم الغاز على درجة حرارة ثابتة
وضغط ثابت يتناسب طرديا مع عدد المولات

- Mathematically, this means $V = kn$

$$\frac{V}{n} = k$$

$$\frac{V_1}{n_1} = \frac{V_2}{n_2}$$

Ideal-Gas Equation

A, B

$A \propto B$

$A \propto 1/B$

- So far we've seen that

عكسي **$V \propto 1/P$ (Boyle's law)**

طردي **$V \propto T$ (Charles's law)**

طردي **$V \propto n$ (Avogadro's law)**

- **Combining these, we get**

$$V \propto \frac{nT}{P}$$

معادلة الغاز المثالي

Ideal-Gas Equation

The relationship

$$V \propto \frac{nT}{P}$$

then becomes

$$V = R\,\frac{nT}{P}$$

or

$$PV = nRT$$

ثابت الغاز العام

Ideal-Gas Equation

The constant of proportionality is known as ***R***, the gas constant.

R: ثابت الغاز

Units	Numerical Value
L-atm/mol-K	0.08206
J/mol-K*	8.314
cal/mol-K	1.987
m^3-Pa/mol-K*	8.314
L-torr/mol-K	62.36

*SI unit

Calcium carbonate, $CaCO_3(s)$, decomposes upon heating to give $CaO(s)$ and $CO_2(g)$. A sample of $CaCO_3$ is decomposed, and the carbon dioxide is collected in a 250-mL flask. After the decomposition is complete, the gas has a pressure of 1.3 atm at a temperature of 31 °C. How many moles of CO_2 gas were generated?

$$CaCO_3(s) \longrightarrow CaO(s) + CO_2(g)$$

$V = 250\,mL \rightarrow 250 \times 10^{-3}\,L$

$P = 1.3\,atm$

$T = 31^\circ C + 273.15 = 304.15$

$n = ??$

$PV = nRT \qquad n = \frac{PV}{RT}$

$$n = \frac{1.3 \times 250 \times 10^{-3}}{0.0821 \times 304.15} = 0.013$$

Densities of Gases

If we divide both sides of the ideal-gas equation by V and by RT, we get

$$\frac{n}{V} = \frac{P}{RT}$$

- We know that
  - moles × molecular mass = mass

$$\boldsymbol{n \times M = m}$$

- So multiplying both sides by the molecular mass (M) gives

$$\boldsymbol{\frac{m}{V} = \frac{PM}{RT}}$$

- Mass ÷ volume = density

- So, $$d = \frac{m}{V} = \frac{PM}{RT}$$

Note: One only needs to know the molecular mass, the pressure, and the temperature to calculate the density of a gas.

$d = \frac{PM}{RT} = \frac{0.939 \times 158.3}{0.0821 \times 398.15} = 4.4 \, g/L$

What is the density of carbon tetrachloride vapor at 714 torr and 125 °C?

CCl4 ... P ... T

① $P = \frac{714 \text{ torr}}{760} = 0.939 \text{ atm}$ | $M = 12 + 4(35.45) = 153.8 \, g/mol$ | $T = 125 + 273.15 = 398.15$

Molecular Mass

We can manipulate the density equation to enable us to find the molecular mass of a gas:

$$d = \frac{PM}{RT}$$

Becomes

$$M = \frac{dRT}{P}$$

Calculate the average molar mass of dry air if it has a density of 1.17 g/L at 21 °C and 740.0 torr.

$M = \frac{dRT}{P}$

$d = 1.17\ g/L$

$R = 0.0821$

$T = 21 + 273.15 = 294.15$

$P = \frac{740}{760} = 0.973\ atm$

$M = \frac{dRT}{P} =$

$M = \frac{1.17 \times 0.0821 \times 294.15}{0.973}$

$M = 29\ g/M$

Gay-Lussac’s law:

The pressure of a sample of gas at constant Volume will vary directly with temperature.

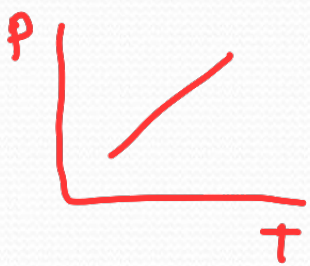
ضغط الغاز بثبوت الحجم يتناسب طرديا مع درجة الحرارة

Temperature & pressure

– As P↑ then T↑

– At constant V, n

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$



P=KT

Gay-Lussac Law

- At **constant volume**, **pressure** and **absolute temperature** are **directly related**.
- $P = k\,T$
- $P_1 / T_1 = P_2 / T_2$

$P = kT$

حجم ثابت

The gas pressure in an aerosol can is 1.5 atm at 25 °C. Assuming that the gas inside obeys the ideal-gas equation, what would the pressure be if the can were heated to 450 °C?

P

$P_1 = 1.5$ atm

$T_1 = 25\,C = 298.15$

$P_2 = ??$

$T_2 = 450\,C + 237.15 = 723.15$

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

$$P_2 = \frac{P_1 T_2}{T_1}$$

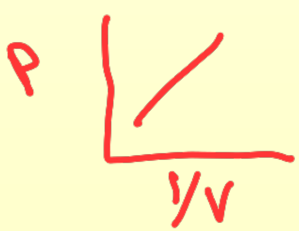
$$P_2 = \frac{1.5\,(723.15)}{298.15}$$

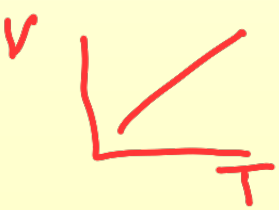
$P_2 = 3.64$ atm

Now What?

- If we combine all of the relationships from the 3 laws covered thus far (Boyle's, Charles's, and Gay-Lussac's) we can develop a mathematical equation that can solve for a situation where 3 variables change :

$PV=k_1$ $\quad$ $V/T=k_2$ $\quad$ $P/T=k_3$





قانون الغاز المجمع

Combined gas law

- The # of moles is held constant
- Is used when you have a change in volume, pressure, or temperature

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

OR

$$P_1V_1T_2 = P_2V_2T_1$$

An inflated balloon has a volume of 6.0 L at sea level (1.0 atm) and is allowed to ascend in altitude until the pressure is 0.45 atm. During ascent the temperature of the gas falls from 22 °C to –21 °C. Calculate the volume of the balloon at its final altitude.

Gas Laws

Boyle's Law

https://www.youtube.com/watch?v=Xto88gMmDzw

Charles' Law

https://www.youtube.com/watch?v=7ZpuMBkf1Ss

Guy Lussac's Law

https://www.youtube.com/watch?v=0Oq7bCSDPxE

Avogadro's Number

https://www.youtube.com/watch?v=S2AM3ZSMNxU

Ideal Gas Equation

https://www.youtube.com/watch?v=-MUtiG6a7uc

https://youtu.be/Cnwh0zl016I

https://www.cliffsnotes.com/study-guides/chemistry/chemistry/gases/quiz-charles-law

$V_1 = 6\,L$

$P_1 = 1\,atm$

$T_1 = 22 + 273.15 = 295.15$

$V_2 = ??$

$P_2 = 0.45\,atm$

$T_2 = -21 + 273.15 = 252.15$

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$V_2 = \frac{P_1 V_1 T_2}{T_1 P_2}$$

$$V_2 = \frac{1 \times 6 \times 252.15}{295.15 \times 0.45} = 11.39\ \ell$$