General Chemistry

CHM1101

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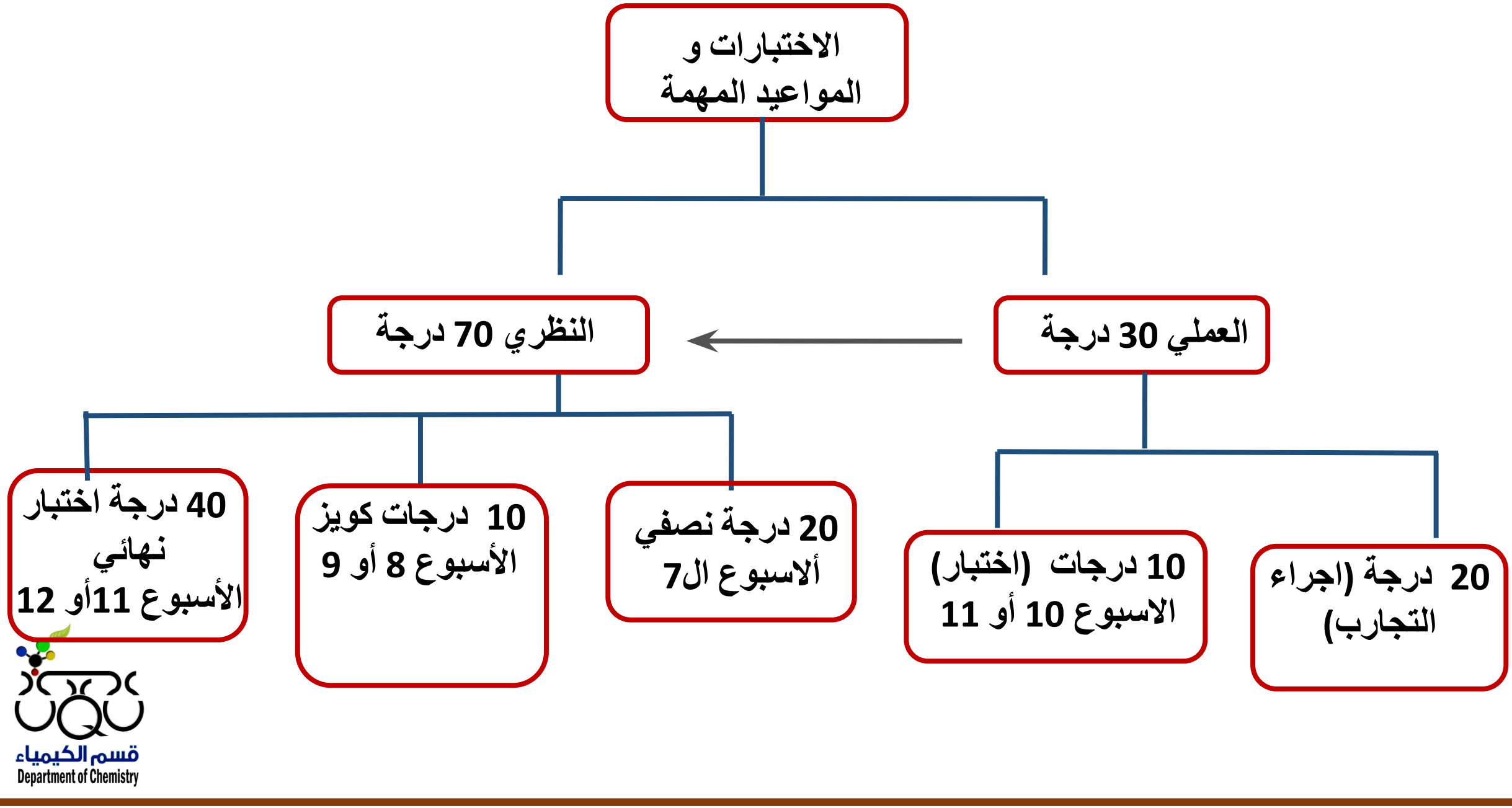

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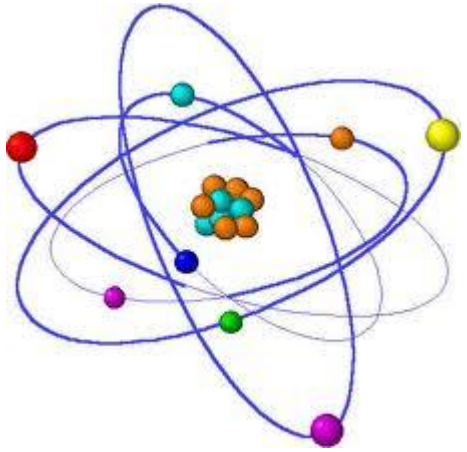
المادة
Matter
القياس
Measurements
Significant figures
الأرقام المعنوية

Chapter
1

COURSE NAME: CHEMISTRY 101
COURSE CODE: 402101-4



What is Chemistry?

The study of matter and the changes it undergoes

الكيمياء :- دراسة المادة و التغيرات التي تحدث لها

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First lecture

Matter

Any thing that occupies space and has space

Separation by physical methods

pure substance

Has a definite composition and distinct properties

Separation by chemical methods

element

cannot be separated into simpler substances by chemical means

compound

composed of two different elements or more chemically united in fixed proportions.

mixture

A combination of two or more substances in which the substances retain their distinct identities

heterogeneous

The composition is not uniform

homogeneous

The composition is the same throughout

NaCl	مركب
Salt water	خليط متجانس
حديد Iron Fe	عنصر
$C_6H_{12}O_6$ sugar	مركب
N_2 O_2 air	خليط متجانس
helium He	عنصر
H_2O water	مركب
salad	خليط غير متجانس

compound مركب

element عنصر

homogeneous mixture خليط متجانس

heterogeneous خليط غير متجانس

NaCl	compound
Salt water	homogeneous mixture
Iron	element
sugar	compound
air	homogeneous mixture
helium	element
water	compound
salad	heterogeneous mixture

compound element homogeneous mixture heterogeneous

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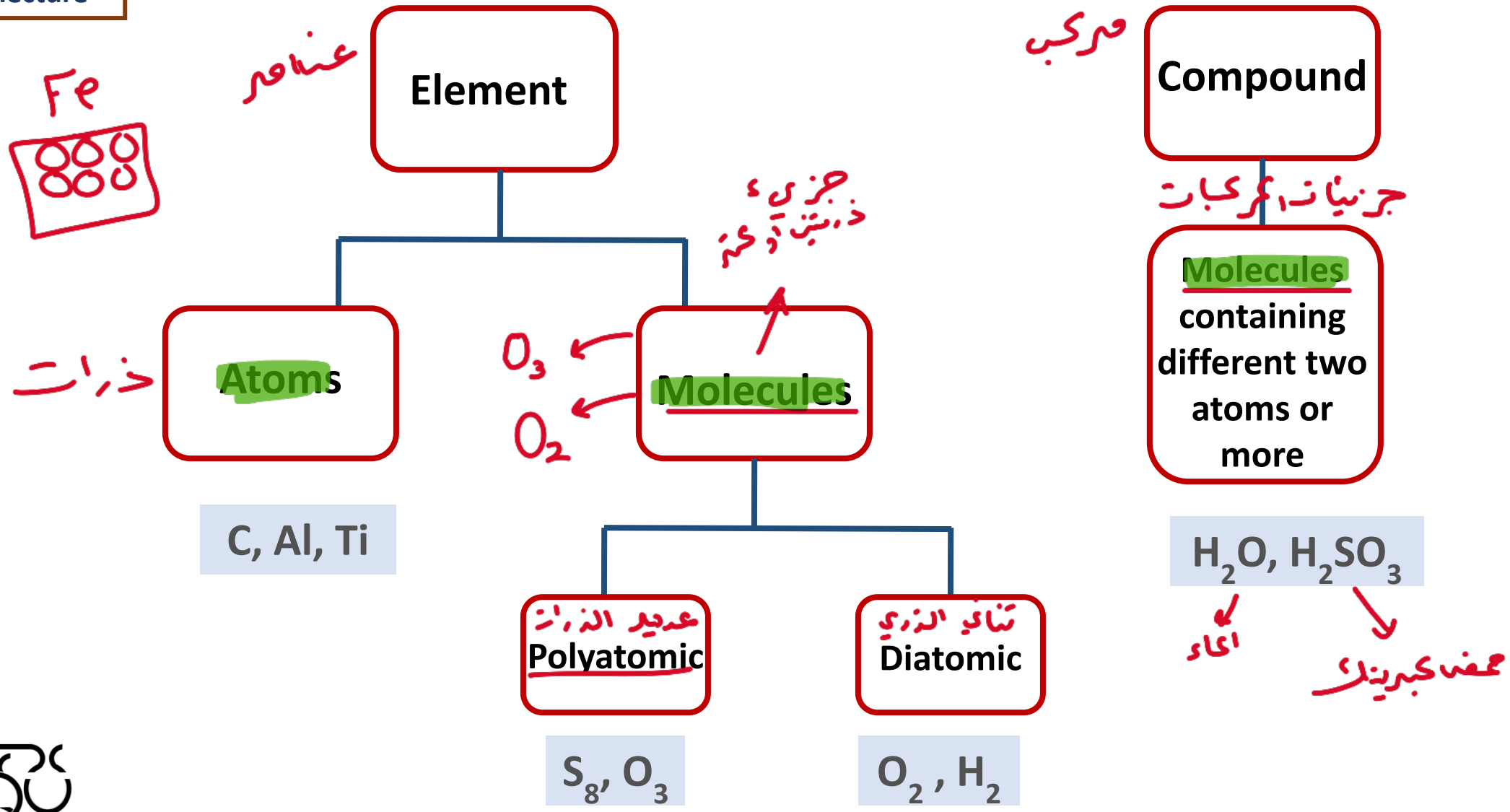

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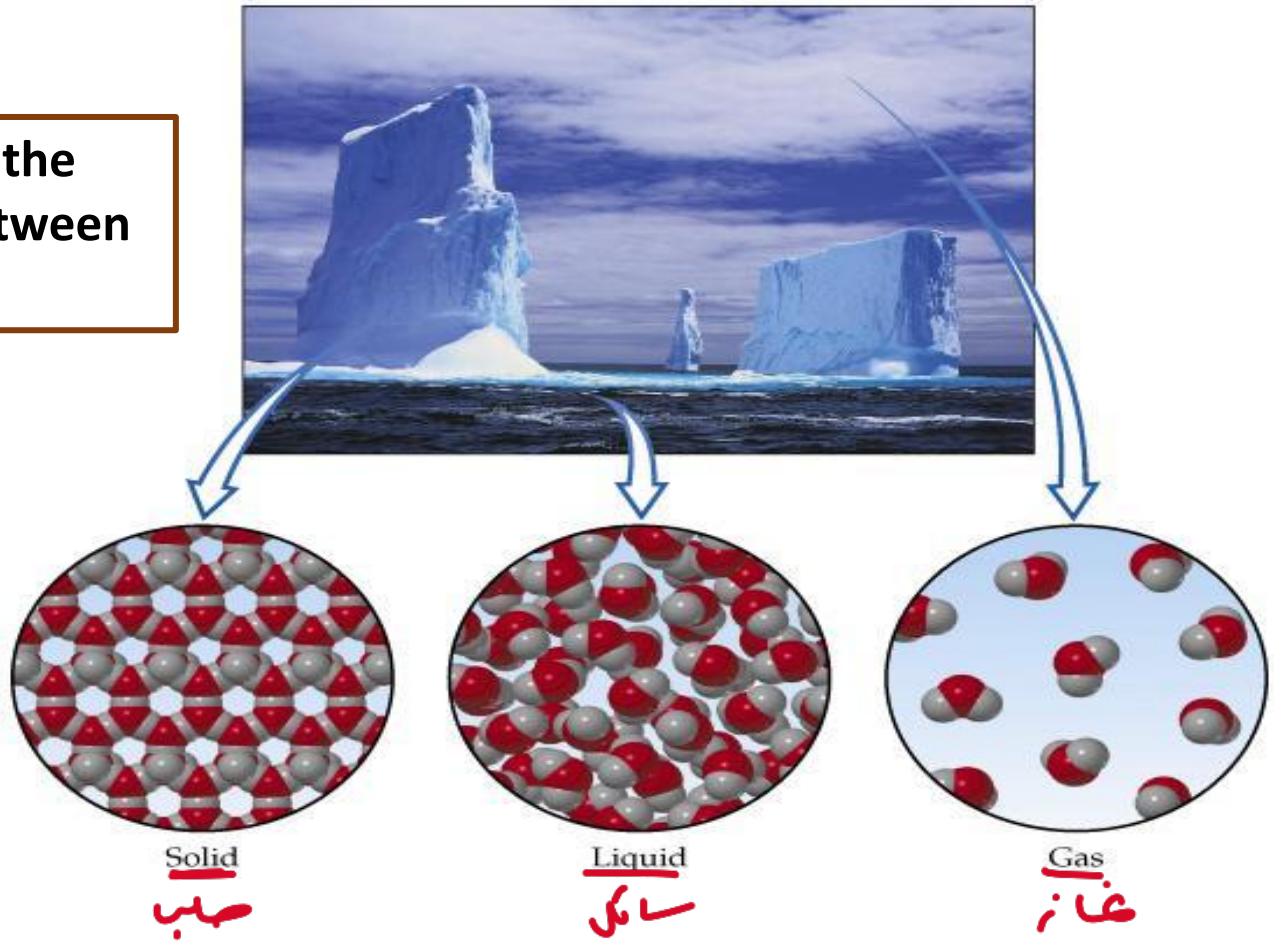
Matter States

The difference between the states is the distance between the molecules.



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Matter properties

خصائص المادة

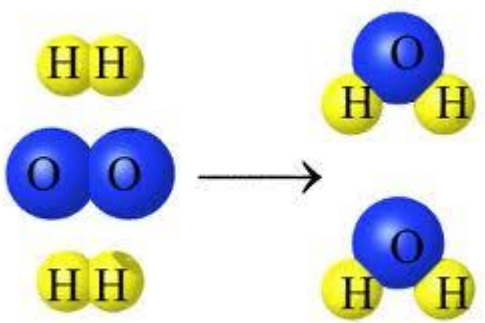
Chemical

كيميائية

is a property when the matter undergoes a chemical change or reaction

reactivity, نشاط التفاعل

flammability قابليته للاشتعال



Physical

فيزيائية

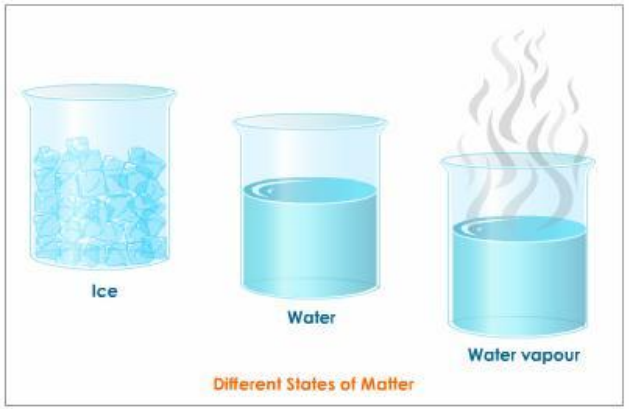
Can be measured and observed without changing the composition or identity of a substances

الخاصية الفيزيائية تمكن القياس عليها دون أن تغير الخاصية التركيب أو الخصائص

color, لون

mass, كتلة

size حجم



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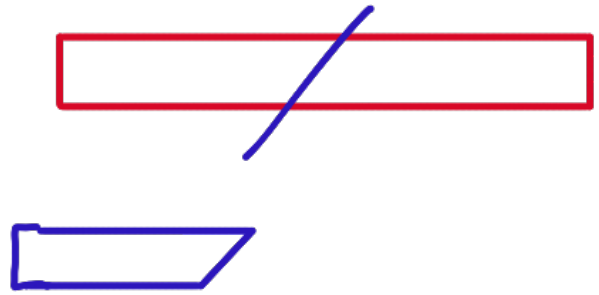

Measurable properties of matter

Extensive

depends on how much matter is being considered

Mass كتلة

volume الحجم

Intensive

Does not depend on how much matter is being considered

Density كثافة

temperature درجة الحرارة

How can these properties be measured ?

القياس

Measurement

SI Units

النظام العالمي للوحدات

International system of units

Symbol	Name of unit	Base Quantity
m	m	
Kg	Kil	
s	Se	
A	An	
K	K	
mol	M	
cd	ca	

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Measurement

SI Units

International system of units

Symbol	Name of unit	Base Quantity
m	meter	Length طول
Kg	Kilogram	Mass کتله
s	Second	Time زمان
A	Ampere	Electrical current ستاره کهربایی
K	Kelvin	Temperature درجه حرارت
mol	Mole	Amount of substance مقدار ماده
cd	candela	Luminous intensity شدت اضاءه

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بادئات Prefixes Used with SI Units

Prefix	Symbol	Multiple of Base Unit
Giga	G	1,000,000,000 or 10^9
Mega	M	1,000,000 or 10^6
kilo	k	1,000 or 10^3
deci	d	0.1 or 10^{-1}
centi	c	0.01 or 10^{-2}
milli	m	0.001 or 10^{-3}
micro	m	0.000001 or 10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}
Femto	f	10^{-15}

m km

5km = 5000 m

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الكتلة الوزن

Mass and weight

kg

What is the difference between mass and weight?

الكتلة مقياس لما يحويه الجسم من مادة

Mass: is a measure of amount of matter in an object

$$1\ Kg = 1000\ g = 1 \times 10^3\ g$$

kg ← ×1000 g

÷1000

Weight: is the force that gravity exerts on an object

الوزن : حقل الجاذبية المؤثر في الجسم

Newton (N)

Volume

الحجم ← m^3 ← الطول × العرض × الارتفاع

Volume – SI derived unit for volume is cubic meter (m^3)

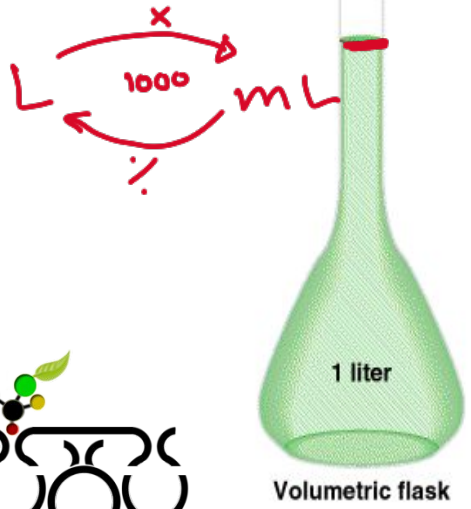
$cm^3 = mL$

$dm^3 = L$

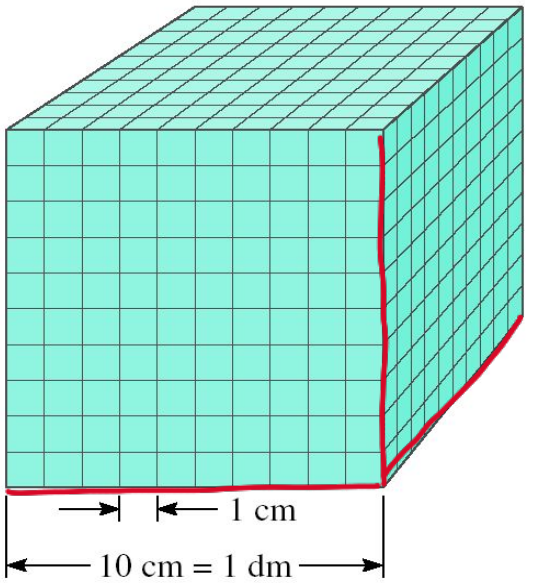
$1\ cm^3 = (1 \times 10^{-2}\ m)^3 = 1 \times 10^{-6}\ m^3$

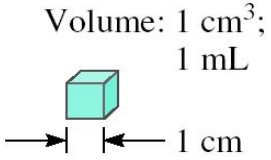
$1\ cm^3 = 1\ mL$

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



Volumetric flask





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Dimensional Analysis Method of Solving Problems

How many mL are in 1.63 L?

Conversion Unit 1 L = 1000 mL

$$1.63\ \cancel{L} \times \frac{1000\ mL}{1\ \cancel{L}} = 1630\ mL$$

$$1.63\ \cancel{L} \times \frac{10^3\ mL}{1\ \cancel{L}} = 1630$$

$1L = 10^3 mL$

$$1.63\ L \times \frac{1L}{1000\ mL} = 0.001630\ \frac{L^2}{mL}$$

الخطوات تحويل L الى mL

$1.63\ L \longrightarrow mL$

1.63×10^3

$1630\ mL$

Density

الكثافه = الكتله / الحجم

الكثافه = الكتله الموجوده في حجم معين

Density is defined as the mass per unit volume.

density = mass/volume $d = \frac{m}{V}$ (m: kg, V: m^3)

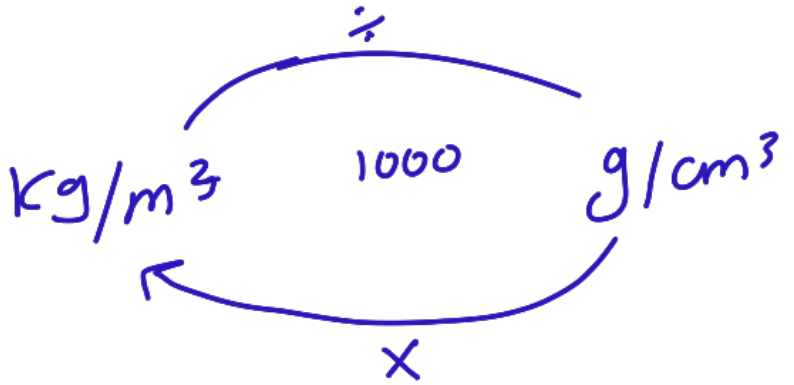
S.I. units for density = **kg/m^3**

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

g/cm^3 for solids — المواد الصلبة

g/ml for liquids — السوائل

g/L for gases — الغازات



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Density

كثافة حجم

A piece of platinum metal with a density of 21.5 g/cm^3 has a volume of 4.49 cm^3. What is its mass?

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

$$m = d \times V$$

$$m = 21.5 \text{ g/cm}^3 \times 4.49 \text{ cm}^3 = 96.5 \text{ g}$$

$$m = d \times V$$

$$= 21.5 \times 4.49 = 96.5 \text{ g}$$

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First lecture

$C = K - 273$

$K = C + 273$

Temperature

Temperature scales

- Fahrenheit ^{o}F
- Celsius ^{o}C
- Kelvin K

$$^{0}F = \left(\frac{9}{5} \times {}^{0}C\right) + 32$$

$32\ ^{0}F = 0\ ^{0}C$

$212\ ^{0}F = 100\ ^{0}C$

$273\ K = 0\ ^{0}C$

$373\ K = 100\ ^{0}C$

$C = 50\ C$

$K = 50 + 273$

$= 323\ K$

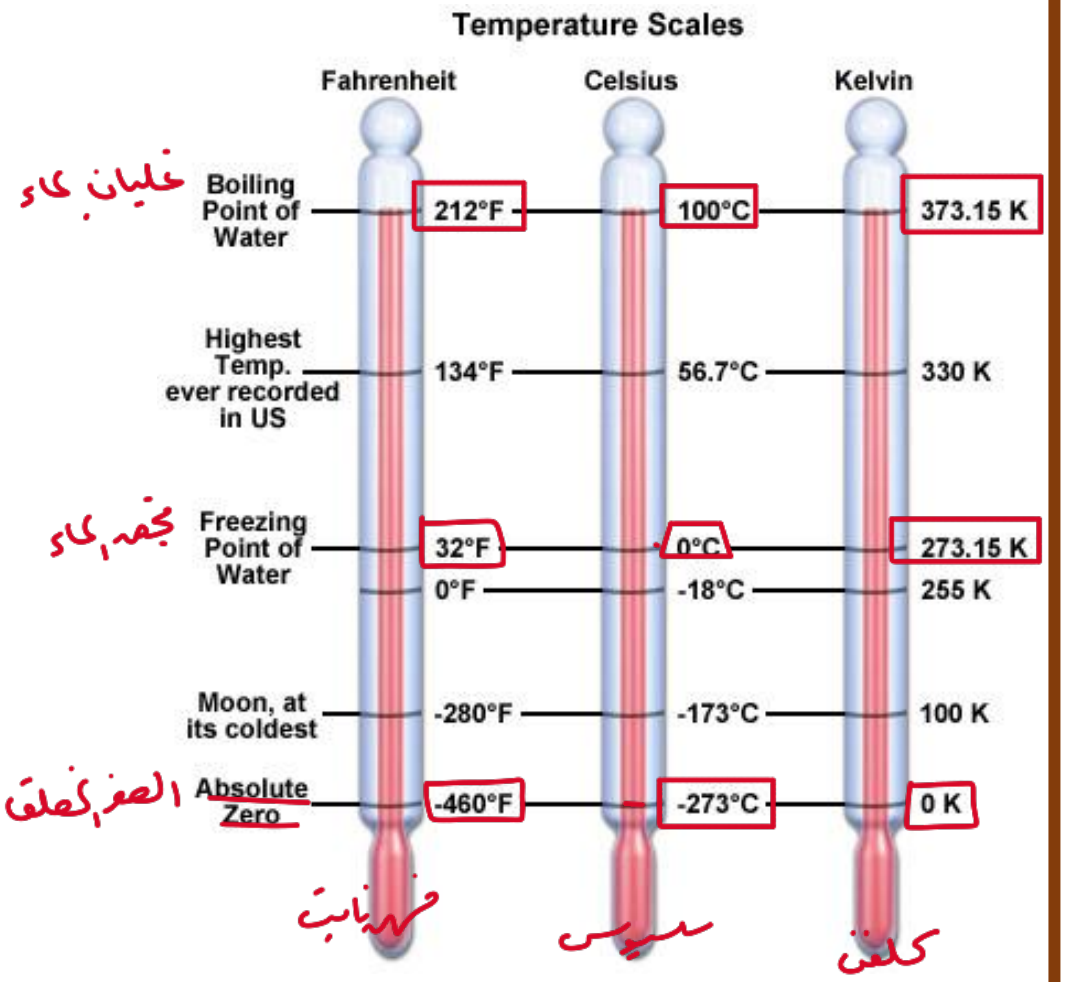
$F = \frac{9}{5} \times C + 32$

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

$100\ C \rightarrow F$

$F = \frac{9}{5} \times 100 - 32$

$212\ F$



$$T(\text{in Kelvin}) = T(\text{in Celsius}) + 273.15$$

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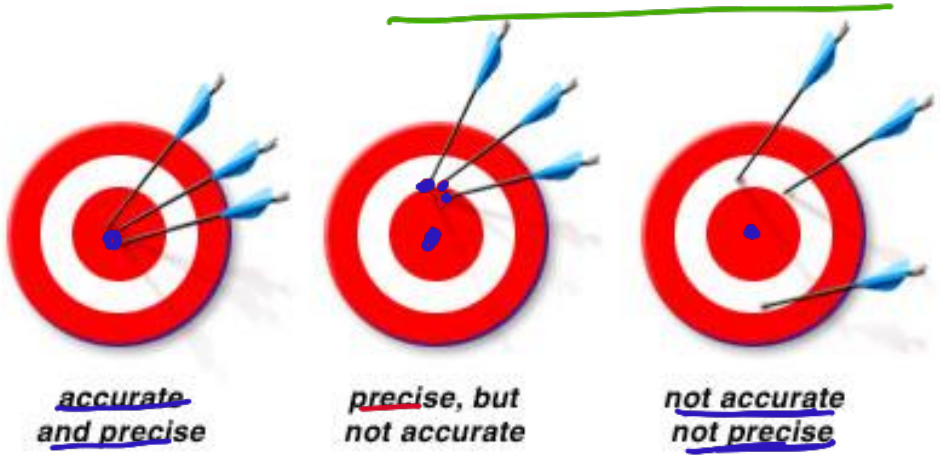
Precision and Accuracy



	Student A	Student B	Student C
	1.964 g	1.972 g	2.000 g
	1.978 g	1.968 g	2.002 g
Average	1.971 g	1.970 g	2.001 g

The true mass of object= 2.000 g

Precision: how close a set of measurements are to each other (reproducibility).

Accuracy: how close your measurements are to the true value.

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Significant Figures

الارقام المعنوية

- Any digit that is not zero is significant

  1.234 kg 4 significant figures

- Zeros between nonzero digits are significant

  606 m 3 significant figures

- Zeros to the left of the first nonzero digit are not significant

  0.08 L 1 significant figure

- If a number is greater than 1, then all zeros to the right of the decimal point are significant

  2.0 mg 2 significant figures

- If a number is less than 1, then only the zeros that are at the end and in the middle of the number are significant

  0.00420 g 3 significant figures

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Singinficant Figures

قواعد الارقام المعنوية

① كل الاعداد غير الصفر هي ارقام معنوية

23.6 = 3 SF

② كل الاصفار داخل العدد وعلى يمين الفاصلة تعتبر ارقام معنوية

1005 ⇒ 4 SF 1.00 ⇒ 3 SF

③ الاصفار على اليسار لا تعد ارقام معنوية

0.0008 ⇒ 1 SF

④ الاصفار على اليمين بدون فاصلة لا تعد ارقام معنوية

1000 ⇒ 1 SF 1000.0 ⇒ 5 SF

⑤ الارقام المكتوبة بالصيغة العلمية لا تعد لارقام الاس

5×10^{5} ⇒ 1 SF 5.3×10^{-6} ⇒ 2 SF

الضرب والقسمة

3.92×4.5

= 15.39

اقل ارقام معنوية هي ② الاجابة 15

الجمع والطرح

12.34 + 5.6

= 17.94

نبحث عن اقل عدد ارقام معنوية بعين الفاصلة (واحد)

17.9

How many significant figures are in each of the following measurements?

1) 24 ml
   - 2 significant figures
2) 3001 g
   - 4 significant figures
3) 0.0320 m^3
   - 3 significant figures
4) 6.4×10^4 molecules
   - 2 significant figures
5) 560 kg
   - 3 significant figures– to clarify use the scientific notation 5.60×10^2 kg

Tip: start to count the sig. fig. from the left when you see a non zero number until the end of the number.

Significant Figures: Addition & Subtraction

If addition or subtraction:

1- must have same power before addition or subtraction

2- sig. fig. in the answer is as the smaller digits after decimal point

3 (2)

Example Y = 232.234 + 0.27 **Find Y.**

Answer 232.50

Y = 232.50

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Significant Figures: Multiplication & Division

When multiplying or dividing numbers, the end result should have the same amount of significant digits as the number with the least amount of significant digits.

الاجابه هي نفس الارقام الصنويه الاقل

$$4.51 \times 3.6666 = 16.53636 \approx 16.5$$

(3 sf) (5 sf) (3 sf)

الاجابه لازم تكون 3 ارقام معنويه

Significant Figures

Exact Numbers

الارقام الدقيقه ارقام ناتجه عن عمليات عد وليس قياس لا تدخل حاسبة ارقام معنويه للنواتج

Numbers from definitions or numbers of objects are considered to have an infinite number of significant figures

المتوسط = مجموع القيم / عددها

The average of three measured lengths; 6.64, 6.68 and 6.70?

$$\frac{6.64 + 6.68 + 6.70}{3} = 6.67333 = 6.67$$

= 7 خطأ

X

≈ 7

Because 3 is an ***exact number***

$$\text{Average} = \frac{6.64 + 6.68 + 6.70}{3} = 6.67$$

sf = 1

Scientific Notation

الصيغة العلمية
55200000.
نحول الرقم الى
رقم بين 1 و 10
5.52 X 10

$N \times 10^n$

n is a positive or negative integer

N is a number between 1 and 10

The number of atoms in 12 g of carbon:

602,200,000,000,000,000,000,000

6.022×10^{23}

0.00023
2.3×10^{-4}

The mass of a single carbon atom in grams:

0.00000000000000000000000199

1.99×10^{-23}

$568.762 = 5.68762 \times 10^{2}$ (6 SF)

$0.0000072 = 7.72 \times 10^{-6}$ (3 SF)

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Question 1

Which of the following is an example of a physical property?

قابليه لاشتعال

A) combustibility

B) corrosiveness التآكل

C) explosiveness الانفجار

D) density

E) A and D

Question 2

Which of the following represents the greatest mass?

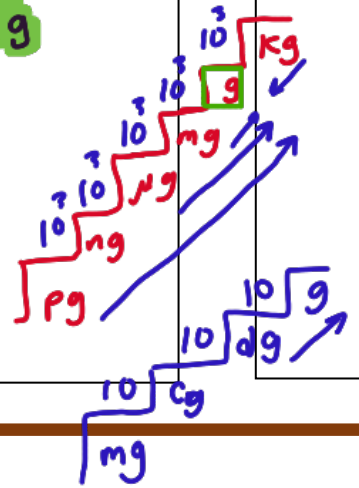
A) 2.0×10^3 mg $2\times10^3\times10^{-3}=2g$

B) 10.0 dg $\times10^{-1}=1g$

C) 0.0010 kg $0.001\times10^3=1g$

D) 1.0×10^6 µg $\times10^{-6}=1g$

E) 3.0×10^{12} pg $\times10^{-12}=3g$



$C = K - 273$

$C_1 = 240 - 273 = -33\ C$

$C_2 = 468 - 273 = 195\ C$

Question 3

Convert 240 K and 468 K to the Celsius scale.

A) 513°C and 741°C

B) -59°C and 351°C

C) -18.3°C and 108°C

D) -33°C and 195°C

Question 4

الحجم

Calculate the volume occupied by 4.50×10^2 g of gold (density = 19.3 g/cm^3).

m

A) 23.3 cm^3

B) 8.69×10^3 cm

C) 19.3 cm^3

D) 450 cm^3

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

$V = \frac{m}{d} = \frac{4.50\times10^2}{19.3}$

$23.3\ cm^3$

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the correct answer.

Question 6

How many significant figures are there in the measurement 3.4080 g?

A) 6 **B)** 5

C) 4 **D)** 3

Question 7

How many significant figures should you report as the sum of 8.3801 + 2.57?

A) 3 **B)** 5

C) 7 **D)** 6

Question 9

The value of 345 mm is a measure of

A) temperature **B)** density

B) **C)** volume **D)** distance **E)** Mass

Question 10

The measurement 0.000 004 3 m, expressed correctly using scientific notation, is

A. 0.43×10^{-5} m B. 4.3×10^{-6}

C. 4.3×10^{-7} D. 4.3×10^{-5}

Question 11

A laboratory technician analyzed a sample three times for percent iron and got the following results: 22.43% Fe, 24.98% Fe, and 21.02% Fe. The actual percent iron in the sample was 22.81%. The analyst's

A) precision was poor but the average result was accurate.

B) accuracy was poor but the precision was good.

C) work was only qualitative.

D) work was precise.

E) C and D.

كلية العلوم التطبيقية
Faculty of Applied Sciences

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Periodic Table

الجدول الدوري

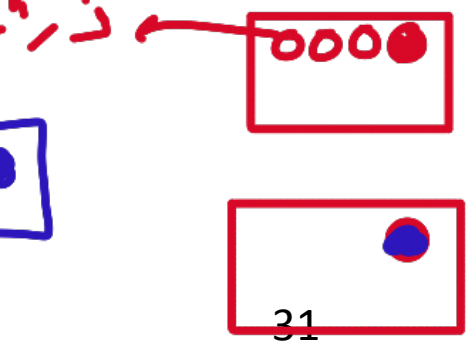
Chapter 2

COURSE NAME: CHEMISTRY 101
COURSE CODE: 402101-4

Dalton's Atomic Theory (1808)

نظرية دالتون

1. Elements are composed of extremely small particles called ***atoms***.
2. All ***atoms*** of a given element are identical, having the same size, mass and chemical properties. The atoms of one element are different from the atoms of all other elements.
3. ***Compounds*** are composed of atoms of more than one element. In any compound, the ratio of the numbers of atoms of any two of the elements present is either an integer or a simple fraction.
4. A ***chemical reaction*** involves only the separation, combination, or rearrangement of atoms; it does not result in their creation or destruction.



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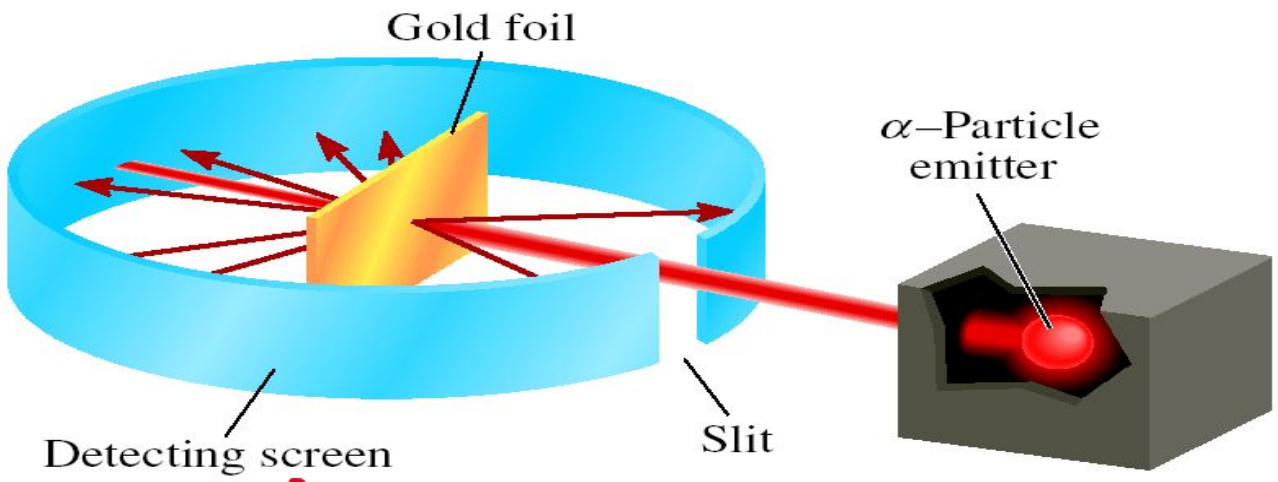
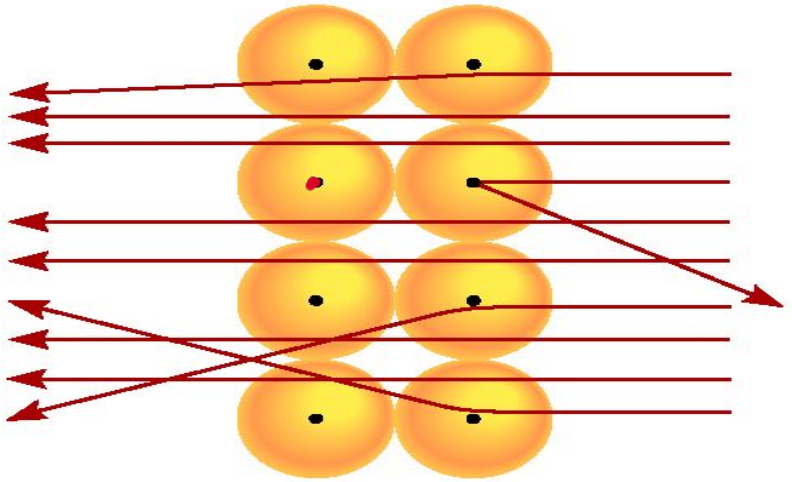
Rutherford's Experiment

(1908 Nobel Prize in Chemistry)





α particle velocity ~ 1.4×10^7 m/s
(~5% speed of light)

1. atoms positive charge is concentrated in the nucleus
2. proton (p) has opposite (+) charge of electron (-)
3. mass of p is 1840 x mass of e^- (1.67×10^{-24} g)

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TABLE 2.1 Mass and Charge of Subatomic Particles

Particle	Mass (g)	Charge: Coulomb	Charge: Charge Unit
Electron* e^-	9.10938×10^{-28}	-1.6022×10^{-19}	-1
Proton p^+	1.67262×10^{-24}	$+1.6022 \times 10^{-19}$	$+1$
Neutron	1.67493×10^{-24}	0	0

*More refined measurements have given us a more accurate value of an electron's mass than Millikan's.

mass p ≈ mass n ≈ 1840 x mass e^-

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Atomic number, Mass number and Isotopes

العدد الذري

Atomic number (Z) = number of protons in nucleus = عدد P

Mass number (A) = number of protons + number of neutrons p+n

عدد الكتلة

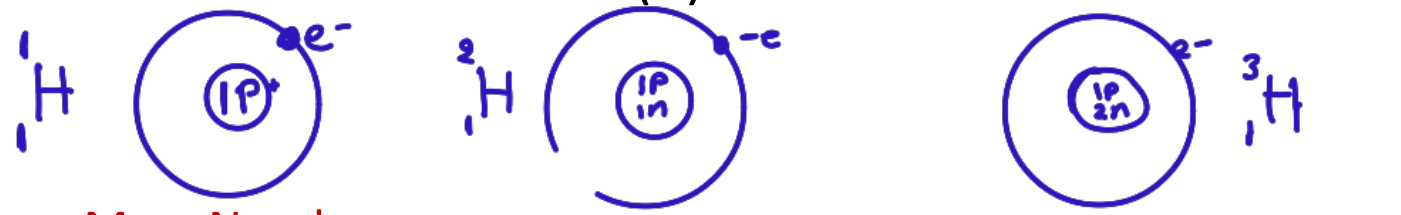
= atomic number (Z) + number of neutrons

$^{23}_{11}Na$ P= 11 e= 11 n= 12

Isotopes are atoms of the same element (X) with different numbers of neutrons in their nuclei

النظائر

ذرات لنفس العنصر لها نفس العدد الذري لكن تختلف في عدد النيوترونات أو العدد الكتلي



Mass Number → A

Atomic Number → Z

X ← Element Symbol

	$^{12}_{6}C$	$^{13}_{6}C$	$^{14}_{6}C$
p	6	6	6
e	6	6	6
n	6	7	8

$^{1}_{1}H$

ديتيريوم $^{2}_{1}H$ (D)

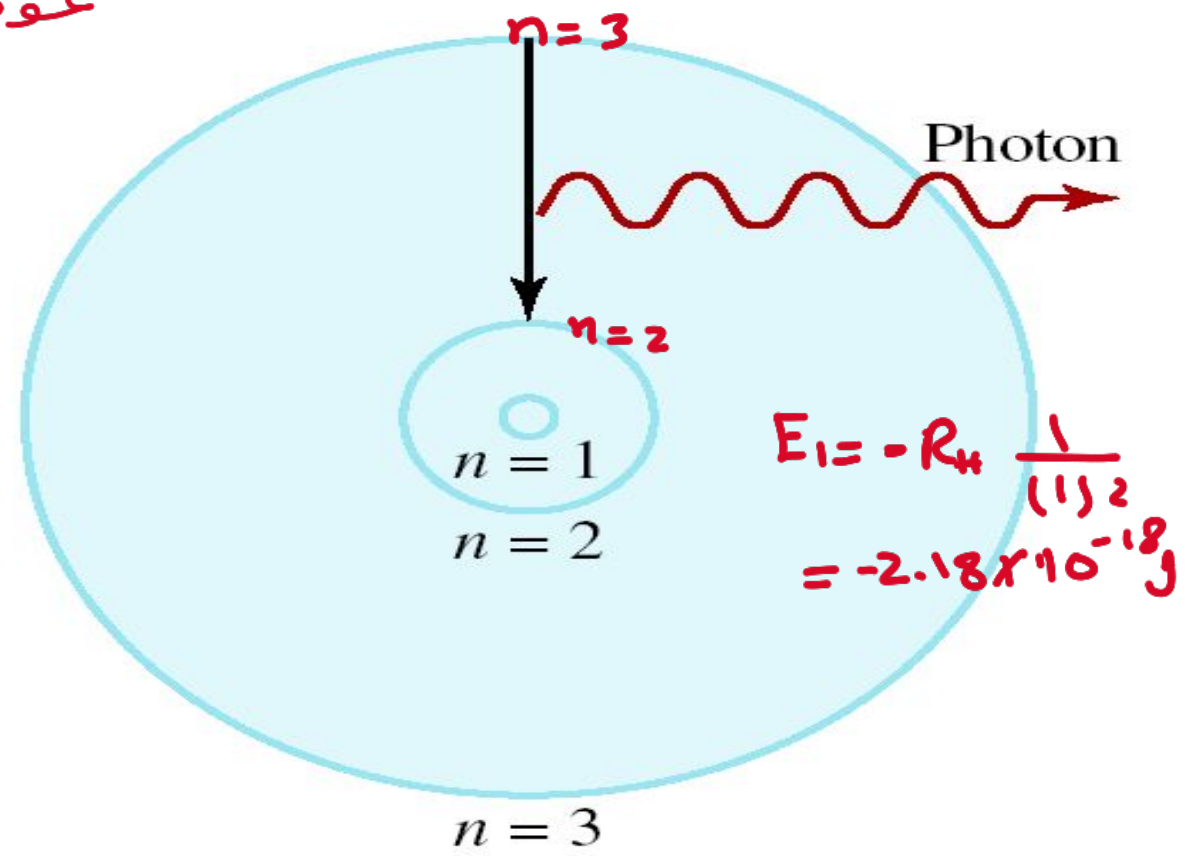
تريتيوم $^{3}_{1}H$ (T)

$^{235}_{92}U$ $^{238}_{92}U$ خطائر اليورانيوم

Bohr's Model of the Atom (1913)

نموذج بور لذرة الهيدروجين

1. e^- can only have specific (quantized) energy values
2. light is emitted as e^- moves from one energy level to a lower energy level



$E_1 = -R_H \frac{1}{(1)^2}$

$= -2.18 \times 10^{-18}$ J

الالكترون له طاقة محددة من الطاقة
ينبعث اشعاع عندما ينتقل الالكترون من مستوى
الى مستوى اقل

$$E_n = -R_H \left(\frac{1}{n^2}\right)$$

$$E_n = -R_H (1/n^2)$$

ثابت ريدبرج

n (principal quantum number) = 1,2,3,…

R_H (Rydberg constant) = 2.18×10^{-18}J

n :- رقم الكم الرئيسي (رقم المستوى)

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Quantum numbers (n, l, m_l, m_s)

الارقام الكمية

رقم الكم الرئيسي

principal quantum number (*n*)

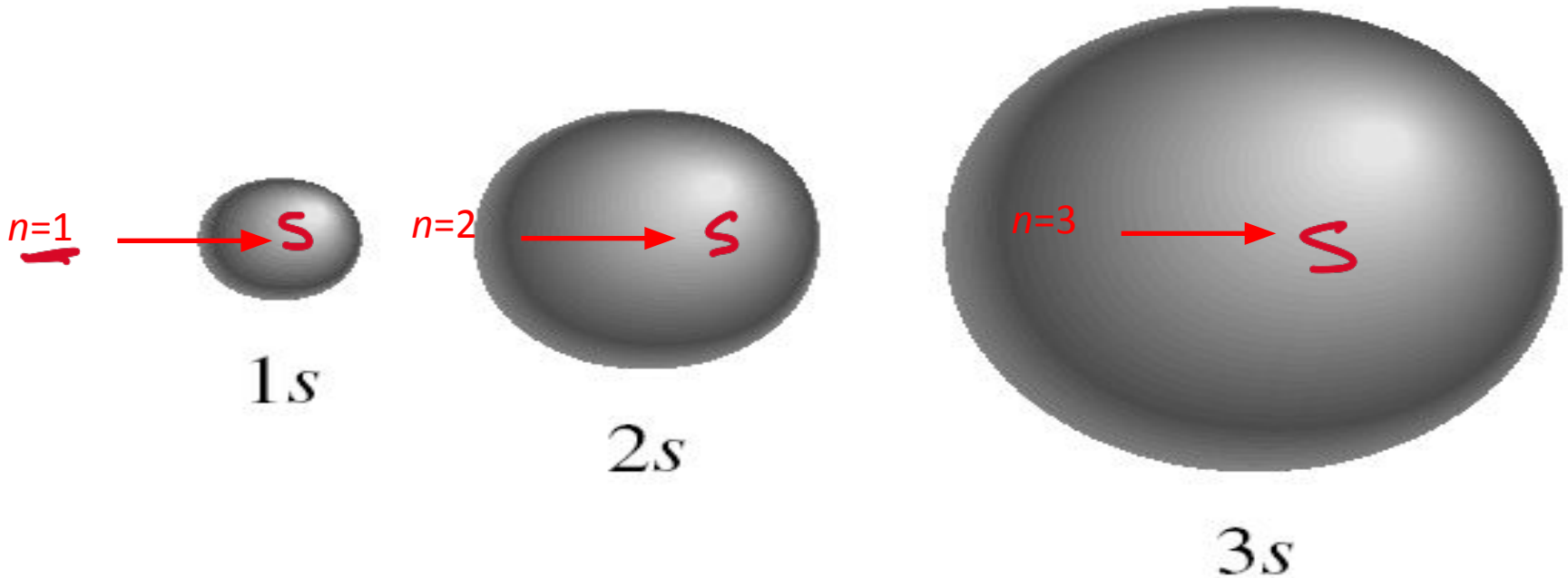
n تمثل رقم المستوى الرئيسي

n = 1, 2, 3, 4,

....

distance of e^- from the nucleus

حيث n تعبر عن بعد الالكترون عن النواة



Angular momentum quantum number (*l*)

Shape of the "volume" of space that the e^- occupies

for a given value of *n*, *l* = 0, 1, 2, 3, … *n*-1

n = 1, *l* = 0
n = 2, *l* = 0 or 1
n = 3, *l* = 0, 1, or 2

l = 0 *s* orbital
l = 1 *p* orbital
l = 2 *d* orbital
l = 3 *f* orbital

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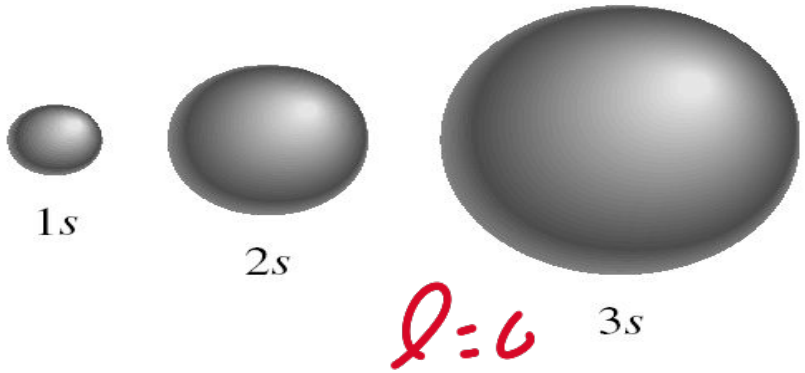
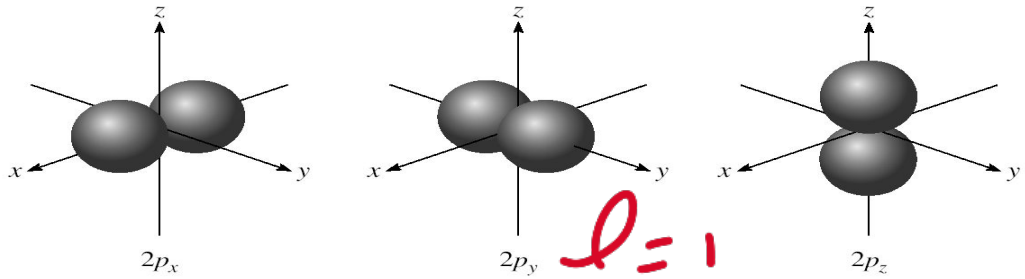
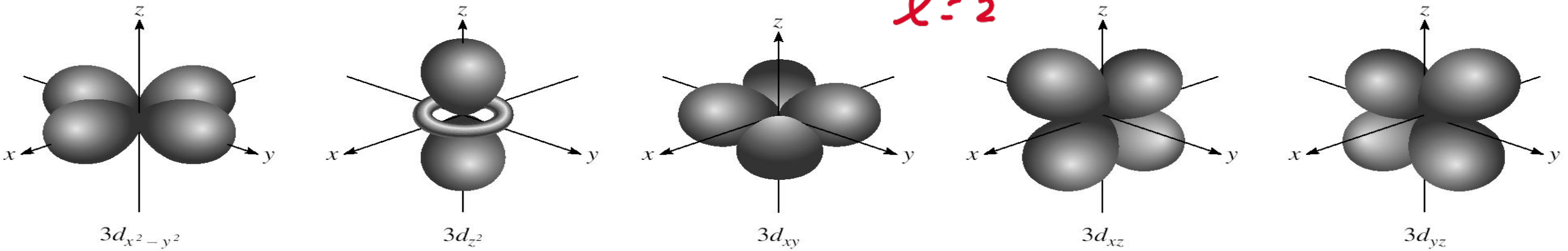
l = 0 (*s* orbitals)



l = 1 (*p* orbitals)





l = 2 (*d* orbitals)

38

magnetic quantum number (m_l)

يعبر عن اتجاه الاوربتال في الفراغ

orientation of the orbital in space

رقم الكم المغناطيسي m_l

for a given value of *l*

m_l = -*l*, …., 0, …. +*l*

$m_l = -l \ldots\ldots l$

3 if *l* = 1 (p orbital), m_l = -1, 0, **or** 1

5 if *l* = 2 (d orbital), m_l = -2, -1, 0, 1, **or** 2

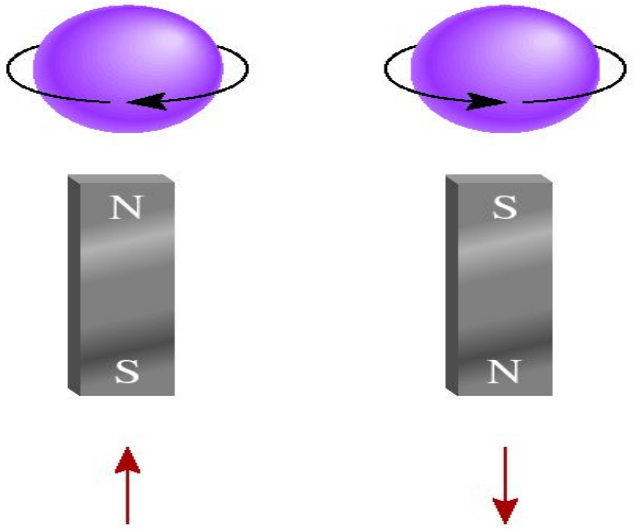
$l=2$ $m_l=-2,-1,0,1,2$

$l=3$ $m_l=-3,-2,-1,0,1,2,3$

spin quantum number (m_s)

رقم الكم المغزلي m_l

m_s = +½ **or** -½



m_s = +½ m_s = -½

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Pauli exclusion principle - no two electrons in an atom can have the same four quantum numbers.

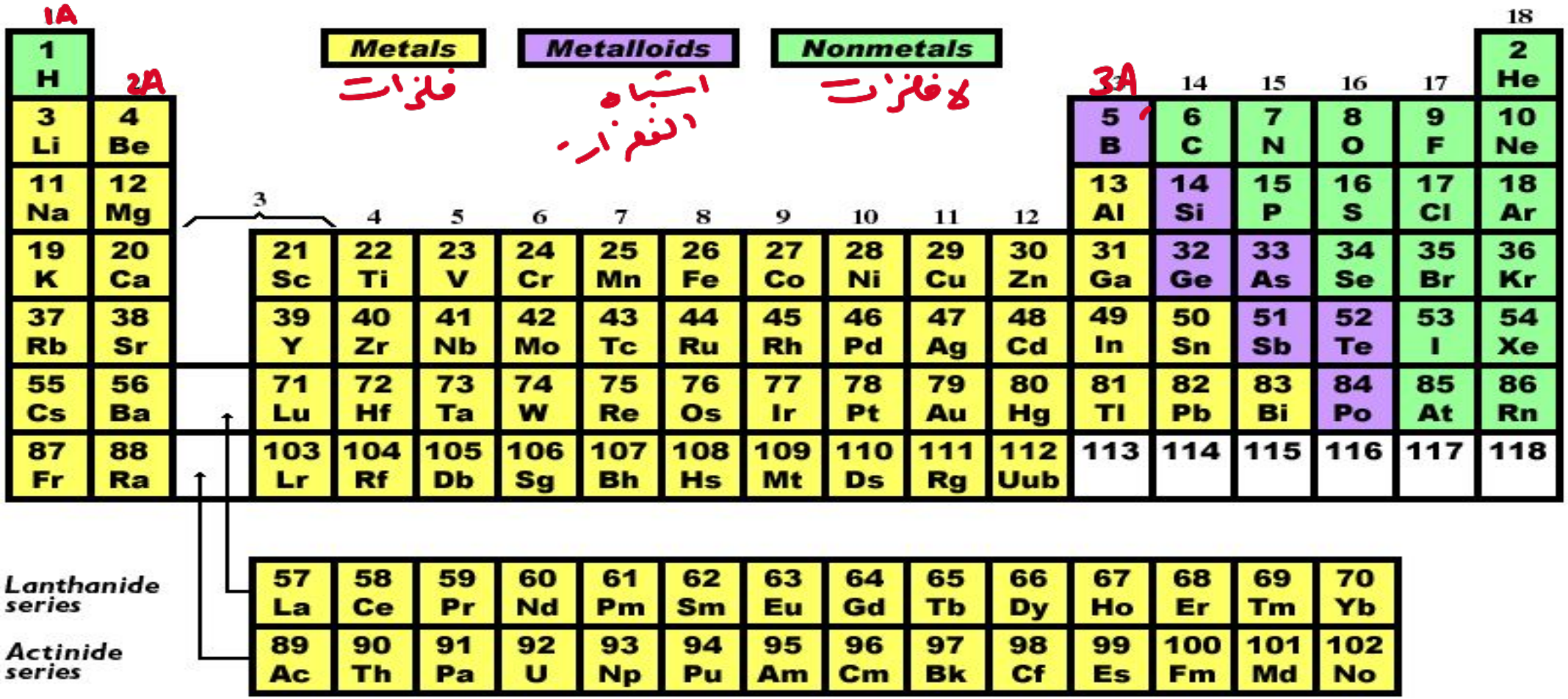
مبدأ الاستبعاد لباولي
لا يوجد إلكترونين لديهما الأربع أرقام الكمية نفسها

TABLE 7.2 Quantum Numbers for the First Four Levels of Orbitals in the Hydrogen Atom

n	ℓ	Orbital Designation	m_ℓ	Number of Orbitals
1	0	$1s$	0	1
2	0	$2s$	0	1
	1	$2p$	$-1, 0, +1$	3
3	0	$3s$	0	1
	1	$3p$	$-1, 0, 1$	3
	2	$3d$	$-2, -1, 0, 1, 2$	5
4	0	$4s$	0	1
	1	$4p$	$-1, 0, 1$	3
	2	$4d$	$-2, -1, 0, 1, 2$	5
	3	$4f$	$-3, -2, -1, 0, 1, 2, 3$	7

	n	l		m_l	e
(2)	n=1	l=0	1S ⊕	0	2
(8)	n=2	l=0		$m_l=0$ 2S ⊕	2
		l=1		$m_l=-1,0,1$ 2P ⇅ ↑ ↑	6
(18)	n=3	l=0		$m_l=0$ 3S ⇅	2
		l=1		$m_l=-1,0,1$ 3P ⇅ ⇅ ↑	6
		l=2		$m_l=-2,-1,0,1,2$ 3d ⇅ ⇅ ⇅ ⇅ ↑	10

Metals, Nonmetals and Metaloids



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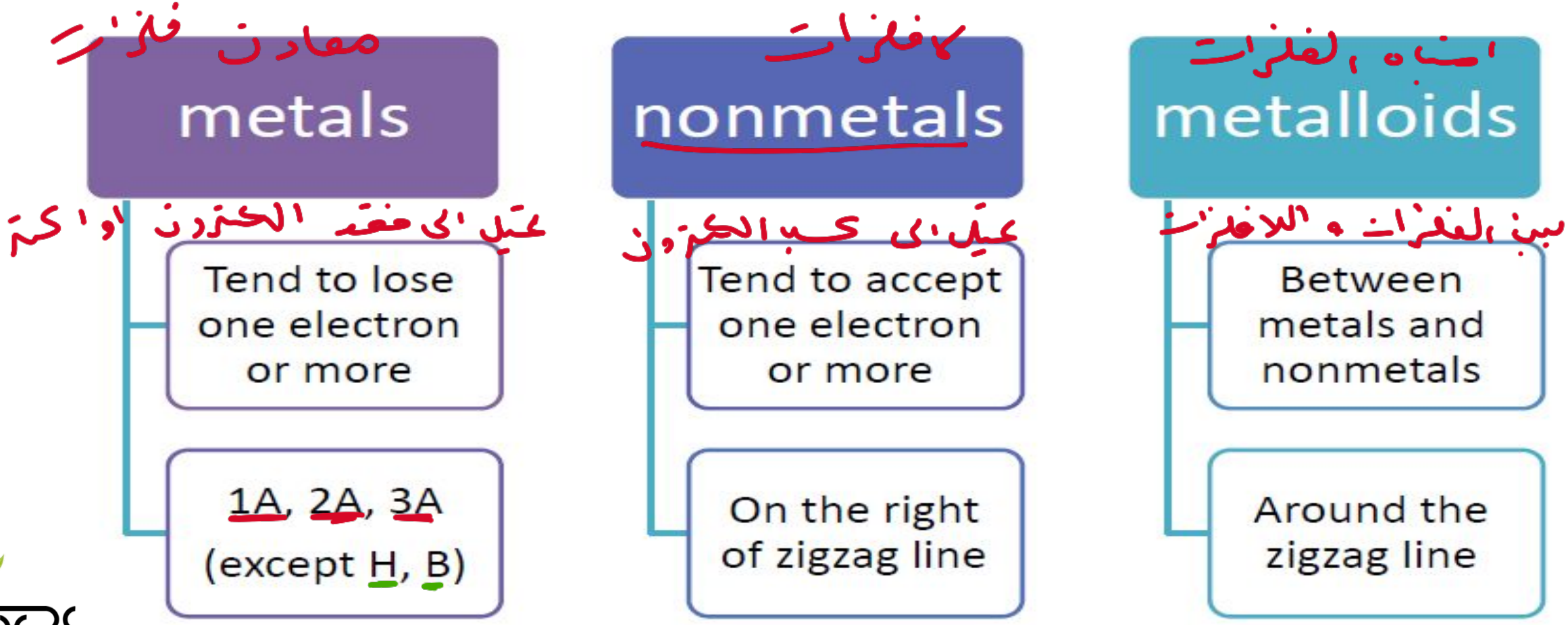
Metals, Nonmetals and Metaloids



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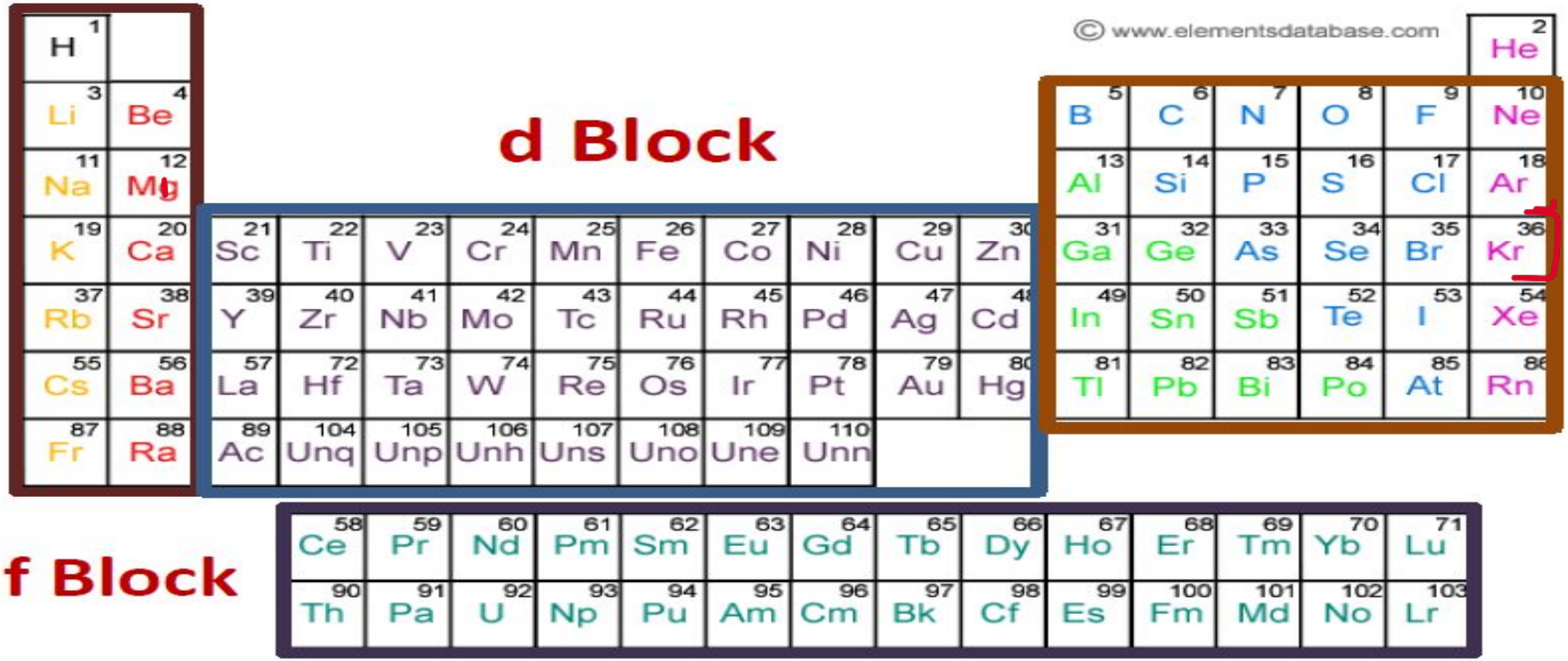
Blocks in Periodic Table



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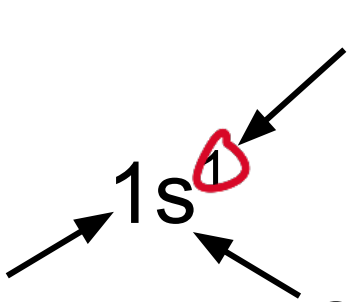
Electron configuration

التوزيع بالالكترون

طريقة توزيع الالكترونات في المدارات

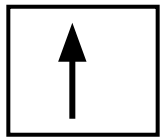
Electron configuration is how the electrons are distributed among the various atomic orbitals in an atom.



S^2
P^6
d^{10}

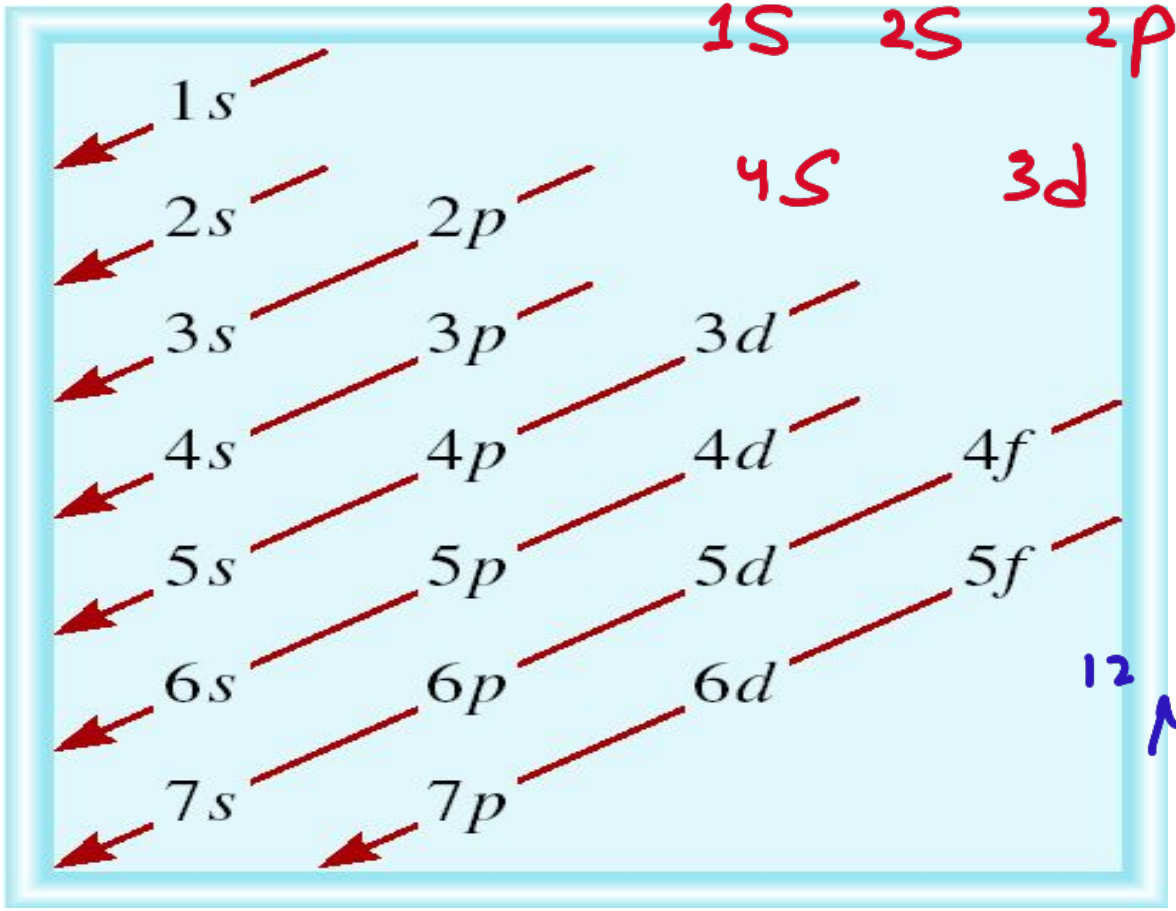
Orbital diagram

H



$1s^1$

Order of orbitals (filling) in multi-electron atom



$1s^2$ $2s^2$ $2p^6$ $3s^2$ 3p

4s 3d 4p 4d

5p 5s

$^{6}C: 1s^2\ 2s^2\ 2p^2$

$^{12}Mg: 1s^2\ 2s^2\ 2p^6\ 3s^2$

1s < 2s < 2p < 3s < 3p < 4s < 3d < 4p < 5s < 4d < 5p < 6s

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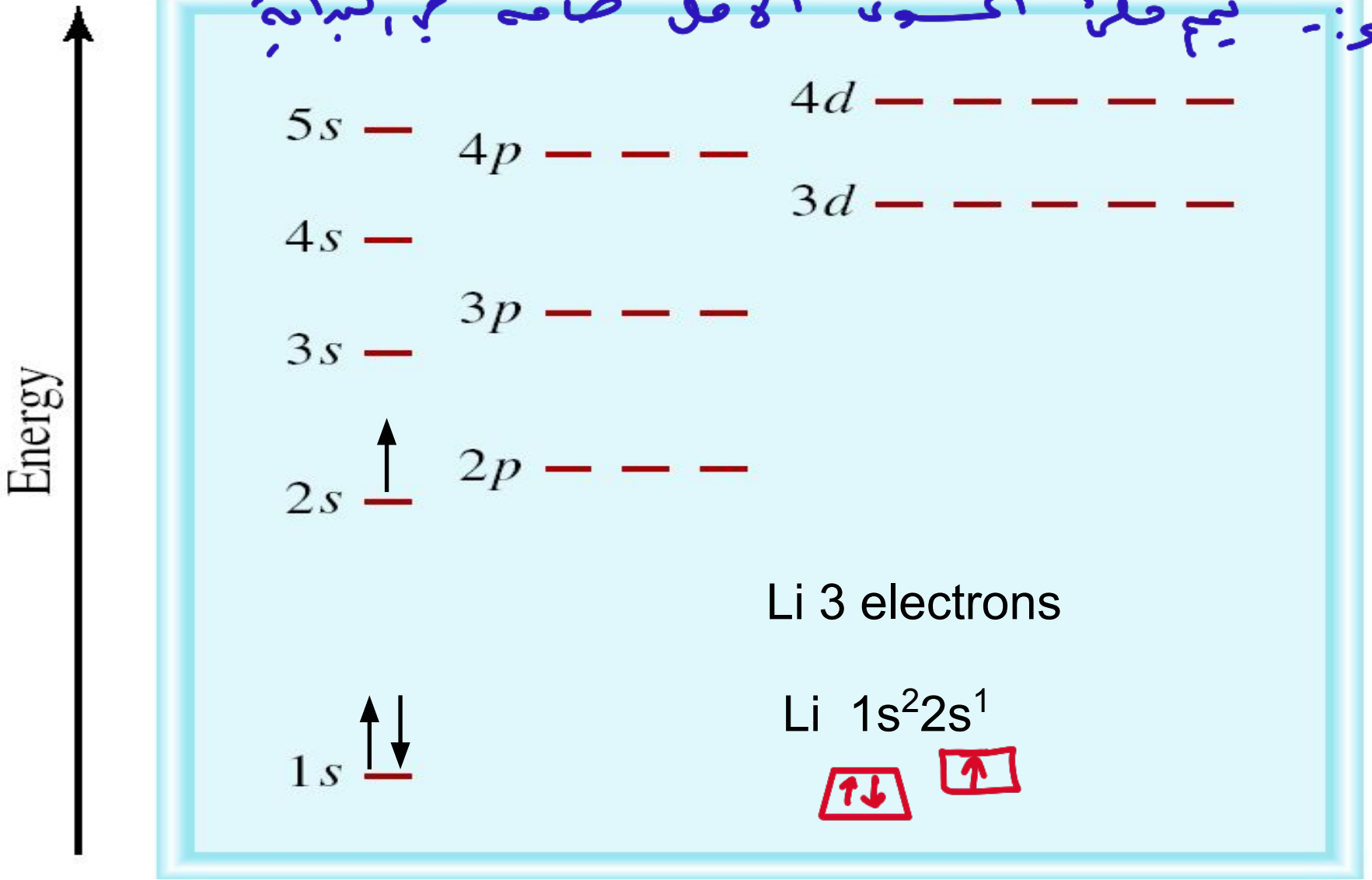
"Fill up" electrons in lowest energy orbitals first (*Aufbau principle*)

اوفبو:- يتم ملئ الكترون الاقل طاقة في البداية



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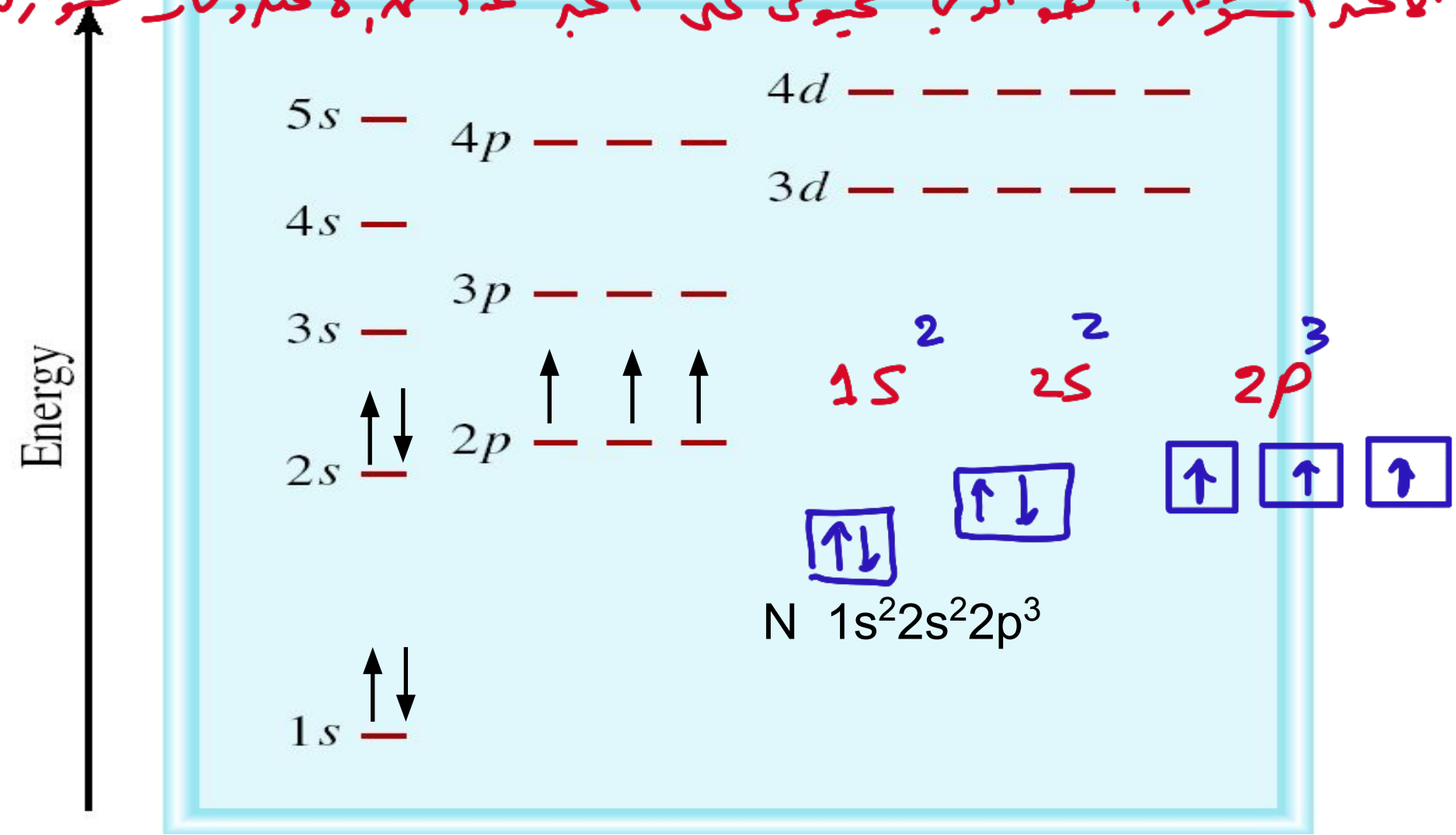
The most stable arrangement of electrons in subshells is the one with the greatest number of parallel spins (***Hund's rule***).



What is the electron configuration of Mg? $1s^2\ 2s^2\ 2p^6\ 3s^2 = [Ne]3s^2$

Mg 12 electrons

$1s^2 2s^2 2p^6 3s^2$

1s < 2s < 2p < 3s < 3p < 4s

2 + 2 + 6 + 2 = 12 electrons

[Ne] $1s^2 2s^2 2p^6$

Abbreviated as $[Ne]3s^2$

طريقة مختصرة للتوزيع الالكتروني

$Cl = 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$

What are the possible quantum numbers for the last (outermost) electron in Cl?

Cl 17 electrons

$1s^2 2s^2 2p^6 3s^2 3p^5$

1s < 2s < 2p < 3s < 3p < 4s

2 + 2 + 6 + 2 + 5 = 17 electrons

$3p^5$

$Cl = [Ne]3s^2 3p^5$

Last electron added to 3p orbital

n = 3 l = 1 m_l = -1, 0, or +1 m_s = ½ or -½

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Chemical Properties of Elements in Periodic Table

خصائص العناصر حسب ترتيبها في الجدول الدوري

نصف قطر الذرة

Atomic Radius

طاقة التأين

Ionization Energy

الالفة الالكترونية

Electronic Affinity

كهروسالبية

Electronegativity

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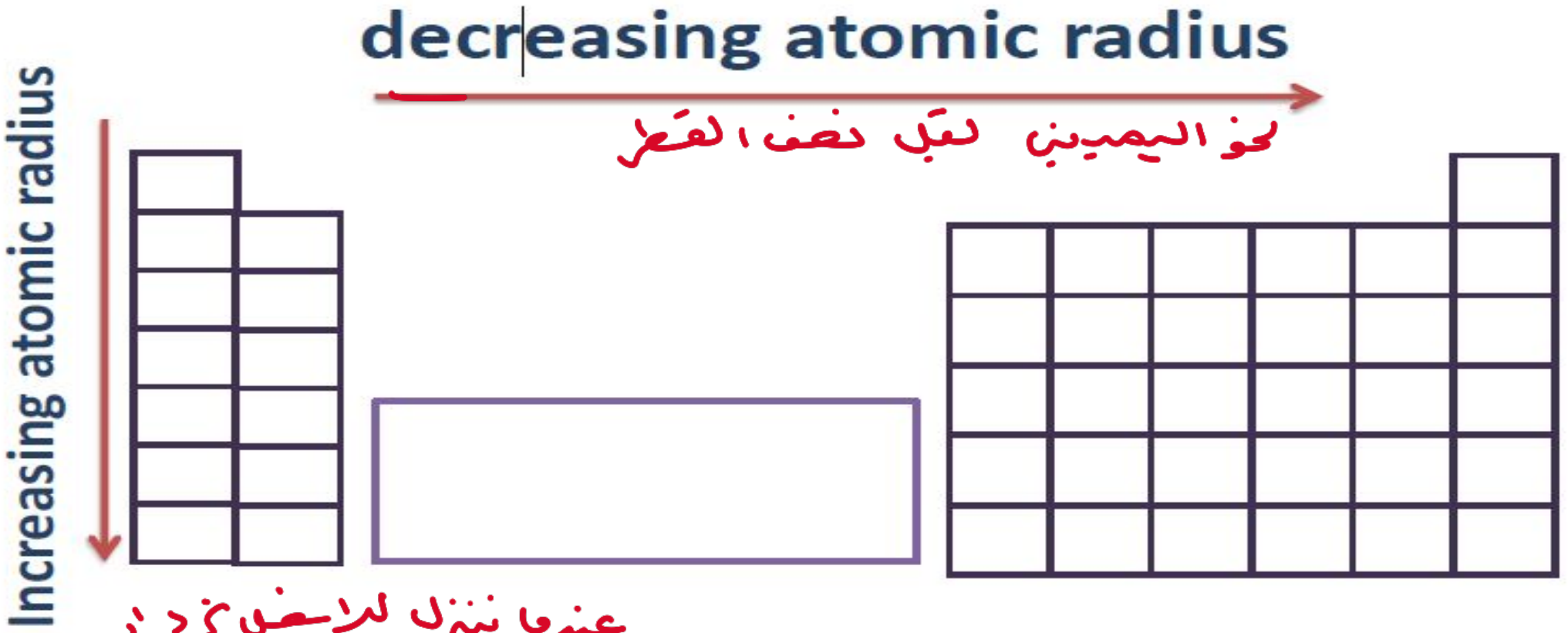
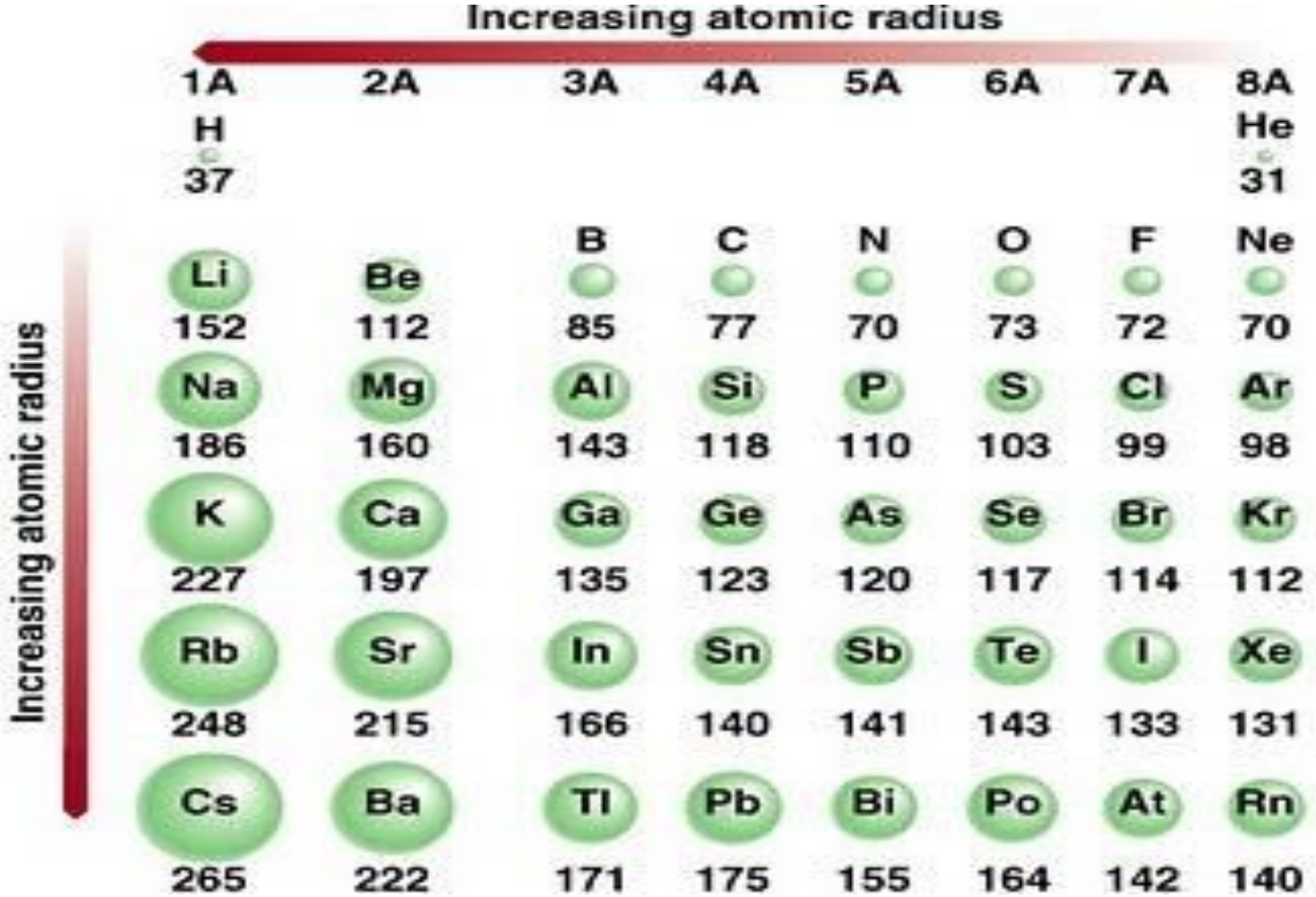
Atomic Radius



Atomic Radius



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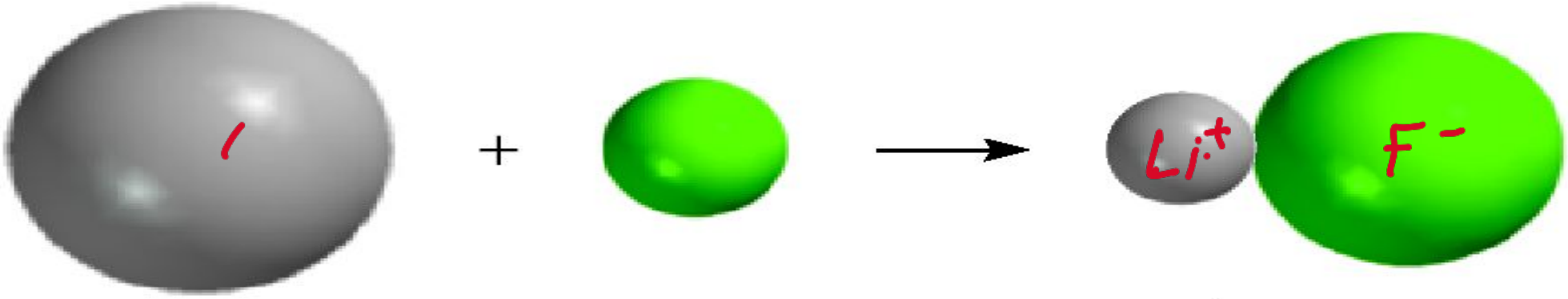
Atomic Radius



الايونات موجبه

Cation is always **smaller** than atom from which it is formed.

الايونات الموجبه حجمها اصغر من ذراتها

Anion is always **larger** than atom from which it is formed.

الايونات السالبه اكبر من حجم ذراتها

Ionization Energy

طاقة التأين

The minimum energy required to remove an electron from a gaseous atom in its ground state

اقل طاقة لازمة لنزع الالكترون من ذرة في الحالة الغازية

$$M\,(g) + \text{energy} = M^{+} + e^{-}$$

طاقة تأين اولى

First ionization $M_{(g)} + IE_1 \longrightarrow M^{+}_{(g)} + e^{-}$

طاقة التأين الثانية

Second ionization $M^{+}_{(g)} + IE_2 \longrightarrow M^{2+}_{(g)} + e^{-}$

طاقة التأين الثالثة

Third ionization $M^{2+}_{(g)} + IE_3 \longrightarrow M^{3+}_{(g)} + e^{-}$

$$IE_1 < IE_2 < IE_3$$

طاقة التأين الاولى اقل من طاقة التأين الثانية والثالثة

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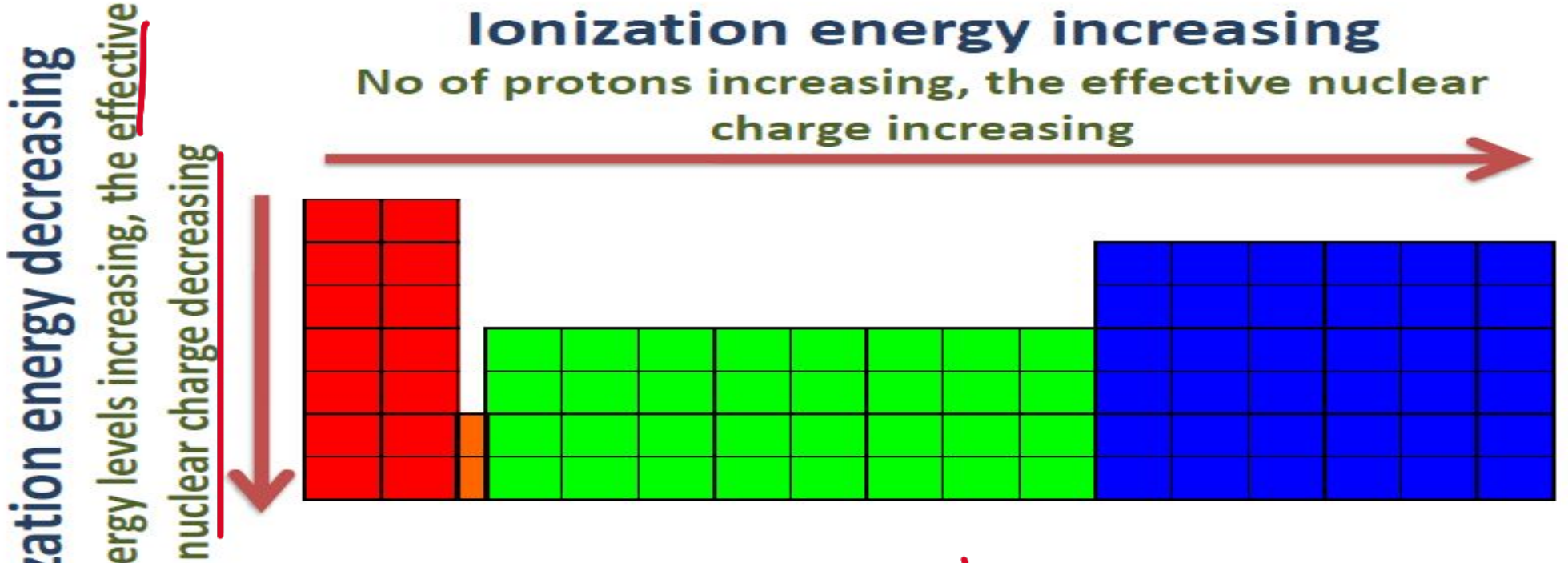
Ionization Energy



كلما تحركنا لليمين زادت طاقة التأين

كلما نزلنا لأسفل قلت طاقة التأين

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الالفة الالكترونية

Electronic Affinity

Electronic affinity is the negative of the energy change that occurs when an electron is accepted by an atom in the gaseous state to form an anion.

التغير السالب في الطاقة الذي يحدث عندما تكتسب الذرة الكترون وتتحول لايون سالب

$Cl + e^- \longrightarrow Cl^-$

$$X_{(g)} + e^- \longrightarrow X^-_{(g)}$$

$$F_{(g)} + e^- \longrightarrow F^-_{(g)} \qquad \Delta H = -328 \text{ kJ/mol} \qquad EA = +328 \text{ kJ/mol}$$

$$O_{(g)} + e^- \longrightarrow O^-_{(g)} \qquad \Delta H = -141 \text{ kJ/mol} \qquad EA = +141 \text{ kJ/mol}$$

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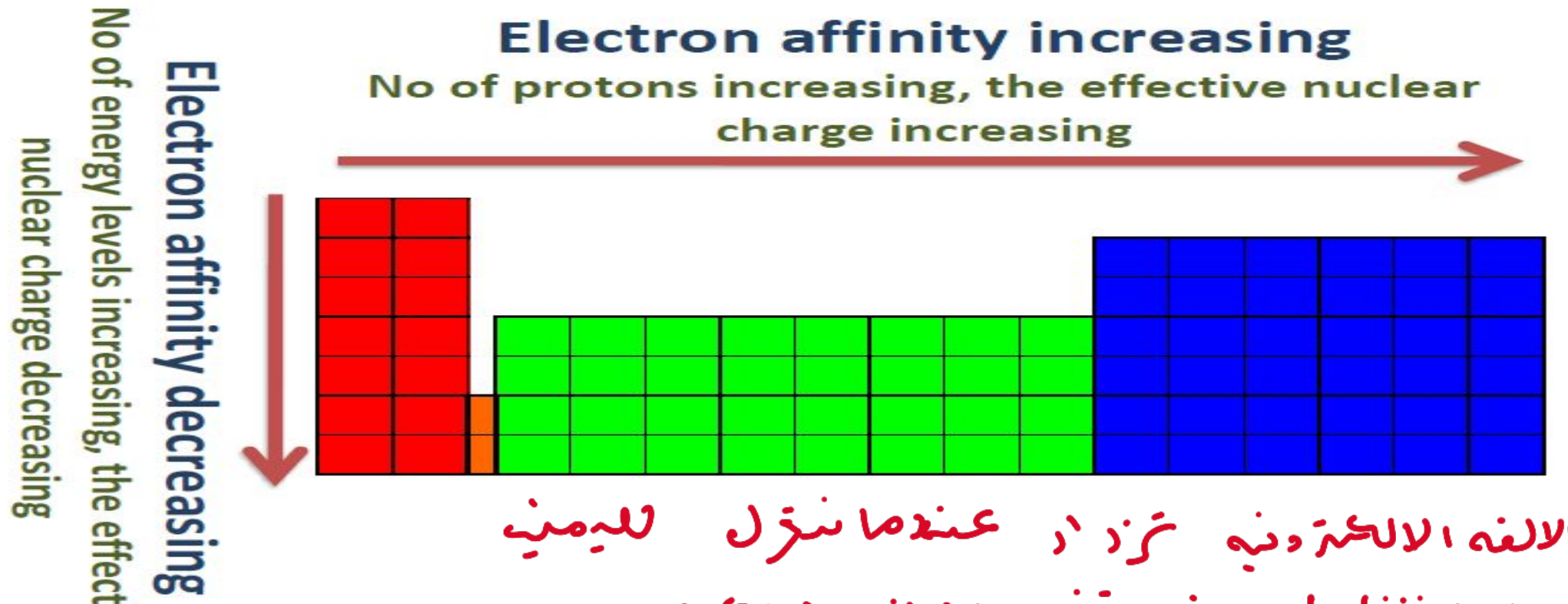
Electronic Affinity



الالفه الالكترونيه تزداد عندما ننزل لليمين

عندما ننزل للاسفل تقل الالفه الالكترونيه

Electronegativity

كهروسالبيه

The ability of an atom to attract toward itself the electrons in a chemical bond

قدره الذره على جذب الالكترونات في الرابطه كوضا

Electronegativity increasing

No of protons increasing, the effective nuclear charge increasing

الى اليمين تزداد الكهروسالبيه

Electronegativity decreasing

No of energy levels increasing, the effective nuclear charge decreasing

نحو الاسفل تقل الكهروسالبيه

F has the greatest value (4.00)

اكثر ذره لديها كهروسالبيه هي F (4)

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Chose the correct answer

1. Protons are located in the nucleus of the atom. A proton has
a) No charge
b) A negative charge
c) A positive and a negative charge
d) A positive charge

2. Neutrons are in the nucleus of the atom. A neutron has
a) A positive charge
b) No charge
c) A negative charge
d) Twice as much positive charge as a proton

3. The atomic number of an atom is
a) The mass of the atom
b) The number of protons added to the number of neutrons
c) The number of protons
d) Negatively charged

4. The atoms of the same element can have different isotopes. An isotope of an atom
a) Is an atom with a different number of protons
b) Is an atom with a different number of neutrons
c) Is an atom with a different number of electrons
d) Has a different atomic number

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$l = 0$ s $l = 1$ p $l = 2$ d

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5. Which one of the following sets of four quantum numbers that most likely describe the last electron of the **Zn atom (Zn atomic number is 30)** ?

a) $n = 3, l = 2, m_l = 2, ms = -½$
b) $n = 3, l = 1, m_l = 1, ms = +½$
c) $n = 3, l = 3, m_l = 2, ms = -½$
d) $n = 4, l = 2, m_l = 0, ms = +½$
e) $n = 4, l = 3, m_l = 3, ms = -½$

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}$

$n=3 \quad l=2$

$m_l = -2,-1,0,1,2$

$m_s = +\frac{1}{2}, -\frac{1}{2}$

6. Which one of the following sets of quantum numbers can correctly represent a **3*p*** orbital?

a.	b.	c.	d.	e.
$n = 3$	$n = 1$	$n = 3$	$n = 3$	$n = 3$
$l = 1$	$l = 3$	$l = 2$	$l = 1$	$l = 0$
$m_l = 2$	$m_l = 3$	$m_l = 1$	$m_l = -1$	$m_l = 1$

A)
B) b
C) c
D) a
E) e

3P $\quad n=3 \quad l=1 \quad m_l = -1,0,1$

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7. True or false?

1. Electrons are found in the nucleus of an atom. False

2. Neutrons and electrons are attracted to one another. False

3.The first energy level of atom is closest to the nucleus. True

8. Fill-in-the-blank

Isotopes

1.Different atoms of the same element can have a different number of _____. neutrons

2.When an atom loses an electron, it forms a _____ positive ion. Cation

3.When an atom gains an electron, it forms a _____ negative ion. anion

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Questions

Choose the correct answer:

1- Tend to accept an electron or more:

a) Metals
b) Nonmetals
c) Metaloids
d) None of the previous

2- The minimum energy required to remove an electron from a gaseous atom in its ground state

a) Atomic radius
b) Ionization energy
c) Electronic affinity
d) Electronegativity

3- The ability of an atom to attract toward itself the electrons in a chemical bond:

a) Atomic radius
b) Ionization energy
c) Electronic affinity
d) Electronegativity

4- First ionization energy is ..... second ionization energy.

a) equals to
b) higher than
c) lower than
d) None of the previous

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Questions

Choose the correct answer:

5- The negative of the energy change that occurs when an electron is accepted by an atom in the gaseous state to form an anion:

a) Atomic radius
b) Ionization energy
c) Electronic affinity
d) Electronegativity

6- Cation is always ……. ….. atom from which it is formed.

a) smaller than
b) larger than
c) equal
d) none of the previous

7- Atoms lose electrons so that …… has a noble-gas outer electron configuration.

a) electrons
b) cation
c) anions
d) atoms

8- The most favorable electronic configuration of Fe^{3+} (Fe atomic number = 26) is:

a) $[Ar]4s^0 3d^5$
b) $[Ar]4s^1 3d^4$
c) $[Ar]4s^2 3d^3$
d) $[Ar]4s^2 3d^5$

Questions

Choose the correct answer:

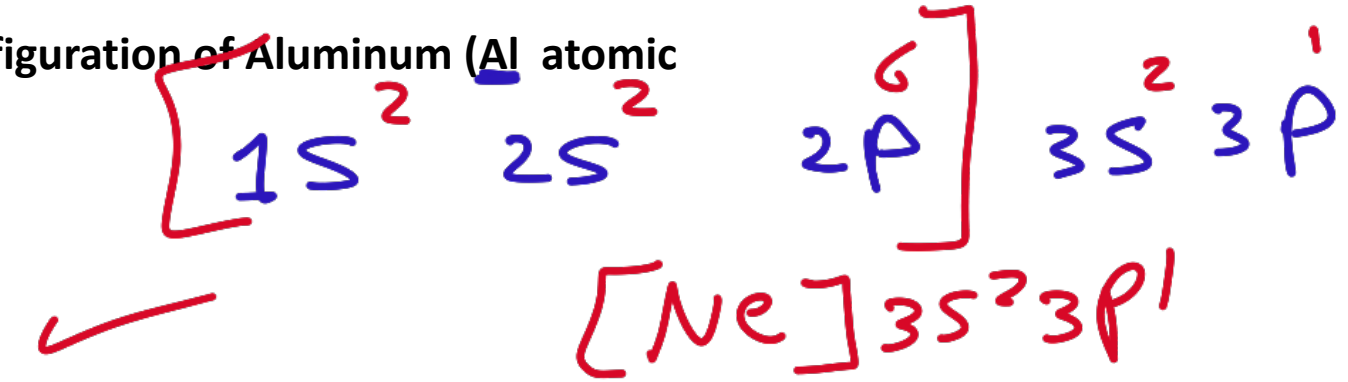
9. The electronic configuration of Aluminum (Al atomic number = 13) is:

a) [Ne] $2s^2 2p^1$

b) [Ne] $2s^1 2p^2$

c) [Ne] $3s^2 3p^1$

d) [Ne] $3s^1 3p^2$



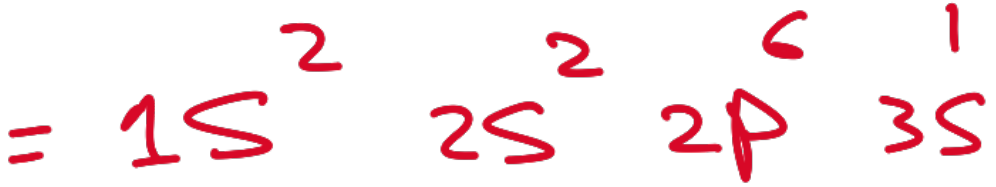
10. The electronic configuration of Sodium (Na atomic number = 11) is:

a) $1s^2 2s^2 2p^6 3s^1$

b) $1s^2 2s^2 2p^5 3s^2$

c) $1s^2 2s^2 2p^7 3s^0$

d) None of the previous



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كلية العلوم التطبيقية
Faculty of Applied Sciences

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Mass relationships:

Atomic and molecular weights
&
moles calculations

Chapter
3

COURSE NAME: CHEMISTRY 101
COURSE CODE: 402101-4

Atomic Mass (amu) وحدة الكتلة الذرية

The mass of an atom in atomic mass units (amu)

6 ← Atomic number

C

12.01 ← Atomic mass

The atomic mass of elements is relative to a standard atom ^{12}C (6 protons, 6 neutrons)

Molar Mass (Atomic weight Aw)

الوزن الذري الكتلة الذرية

The mass of an element atoms per one mole (g/mol)

= Atomic Mass numerically

كتلة ذرات العنصر لكل مول

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Mole (mol)

The amount of a substance that contains as many elementary particles (atoms, molecules or ions), where each mole has number of 6.022×10^{23} particles.

1 mole= 6.022×10^{23} particles = Avogadro's number N_a

1 mol Al = 6.02×10^{23} atoms

1 mol CO_2 = 6.02×10^{23} molecules

1 mol NaCl = 6.02×10^{23} Na^+ ions = 6.02×10^{23} Cl^- ions

The number of atoms in exactly 12 g of ^{12}C is one mole

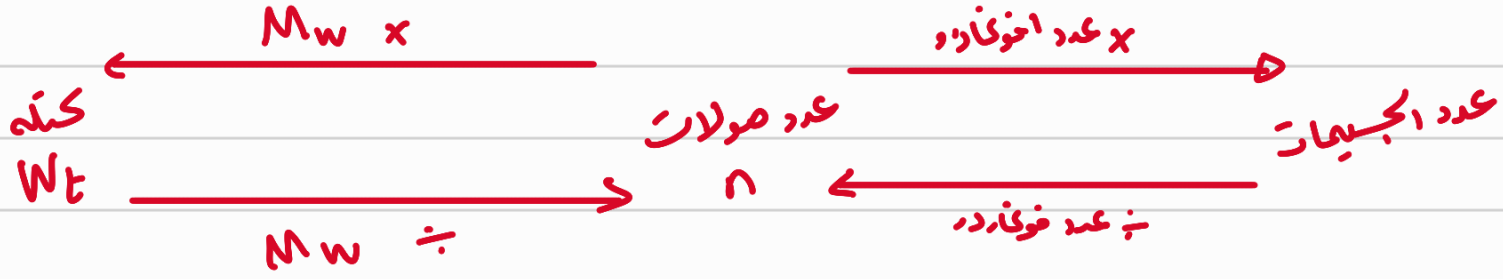
عدد الجسيمات = عدد المولات × عدد أفوجادرو

Aw :- الكتلة الذرية (كتلة مول واحد من العنصر)
تحسب مباشرة من الجدول الدوري

Mw :- الكتلة الجزيئية (كتلة مول من المركب)
تحسب بجمع كل الكتل للعناصر في المركب

عدد المولات = الكتلة (g) / الكتلة المولية = Wt / Mw

الكتلة = عدد المولات × الكتلة المولية
Wt(g) = n × Mw



Molar Mass (Atomic weight A_w):

mass (weight) of 1 mole of atoms in grams

كتلة مول ذرة بالجرام = Aw

1 mol C atoms = 12.01 g A_w of C = 12.01* g/mol

1 mol Cl atoms = 35.45 g A_w of Cl = 35.45* g/mol

1 mol Fe atoms = 55.85 g A_w of Fe = 55.85* g/mol

*(get from periodic table)

للعناصر نحصل عليها من الجدول الدوري

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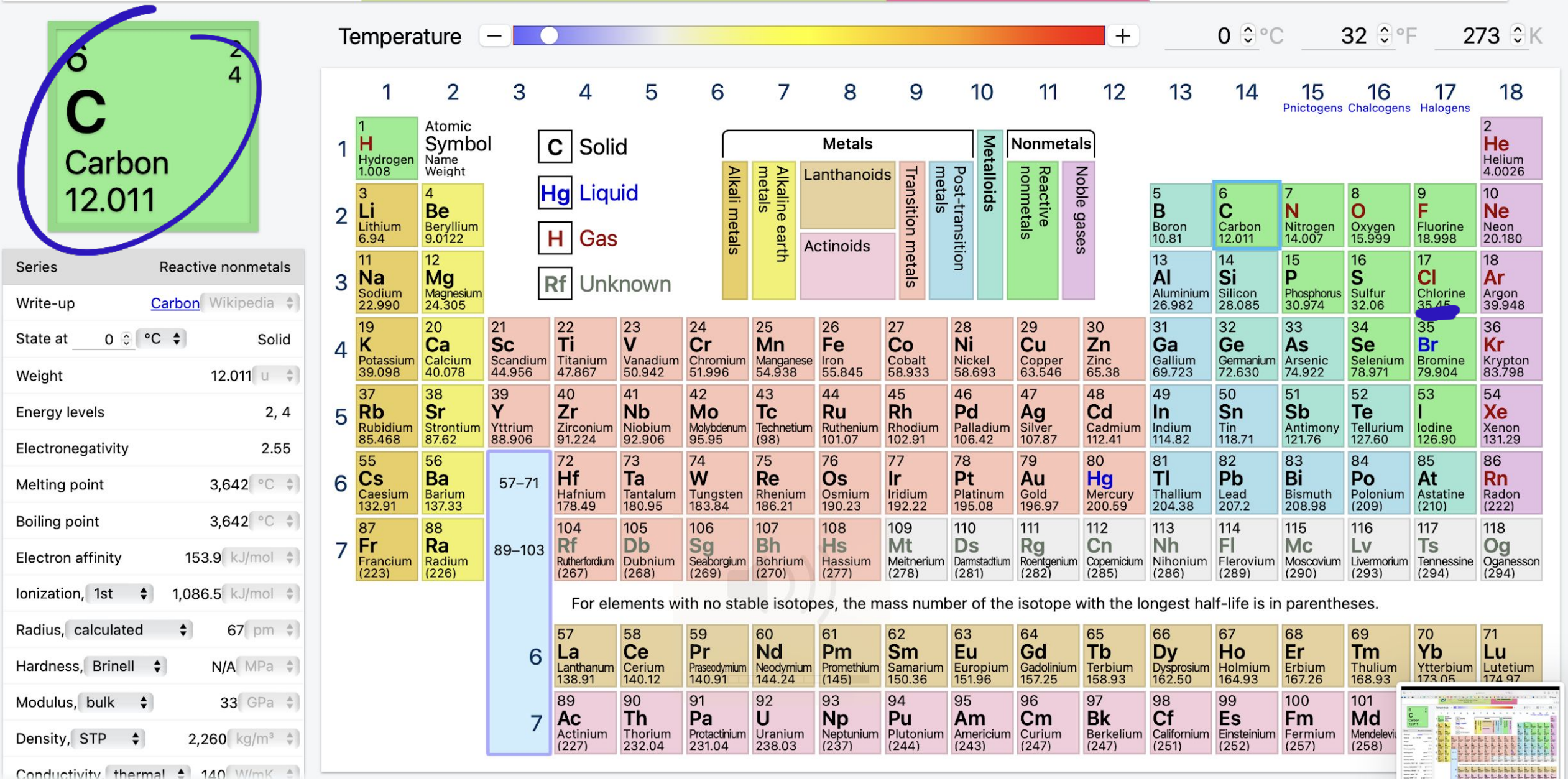
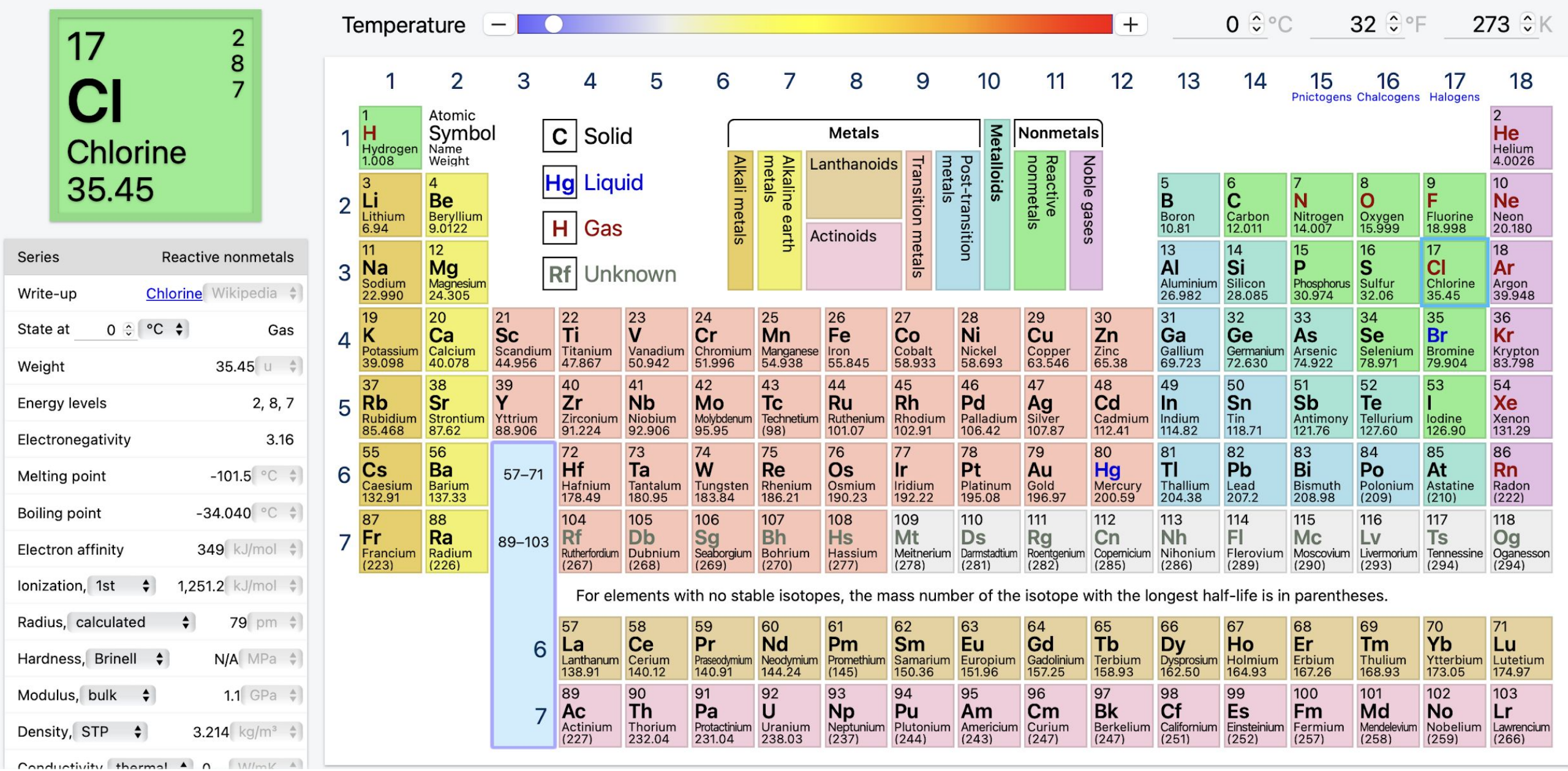
Think: What is the difference between the mass and weight?


6
C
Carbon
12.011
2
4
Temperature
0 °C
32 °F
273 K
Series
Reactive nonmetals
Write-up
Carbon Wikipedia
State at 0 °C
Solid
Weight
12.011 u
Energy levels
2, 4
Electronegativity
2.55
Melting point
3,642 °C
Boiling point
3,642 °C
Electron affinity
153.9 kJ/mol
Ionization, 1st
1,086.5 kJ/mol
Radius, calculated
67 pm
Hardness, Brinell
N/A MPa
Modulus, bulk
33 GPa
Density, STP
2,260 kg/m³
Conductivity, thermal
140 W/mK
Atomic
Symbol
Name
Weight
C Solid
Hg Liquid
H Gas
Rf Unknown
Metals
Alkali metals
Alkaline earth metals
Lanthanoids
Actinoids
Transition metals
Post-transition metals
Metalloids
Nonmetals
Reactive nonmetals
Noble gases
Pnictogens
Chalcogens
Halogens
57–71
89–103
For elements with no stable isotopes, the mass number of the isotope with the longest half-life is in parentheses.


17
2
8
7
Cl
Chlorine
35.45
Temperature
0 °C
32 °F
273 K
Series Reactive nonmetals
Write-up Chlorine Wikipedia
State at 0 °C Gas
Weight 35.45 u
Energy levels 2, 8, 7
Electronegativity 3.16
Melting point -101.5 °C
Boiling point -34.040 °C
Electron affinity 349 kJ/mol
Ionization, 1st 1,251.2 kJ/mol
Radius, calculated 79 pm
Hardness, Brinell N/A MPa
Modulus, bulk 1.1 GPa
Density, STP 3.214 kg/m³
Atomic
Symbol
Name
Weight
C Solid
Hg Liquid
H Gas
Rf Unknown
Metals
Alkali metals
Alkaline earth metals
Lanthanoids
Actinoids
Transition metals
Post-transition metals
Metalloids
Nonmetals
Reactive nonmetals
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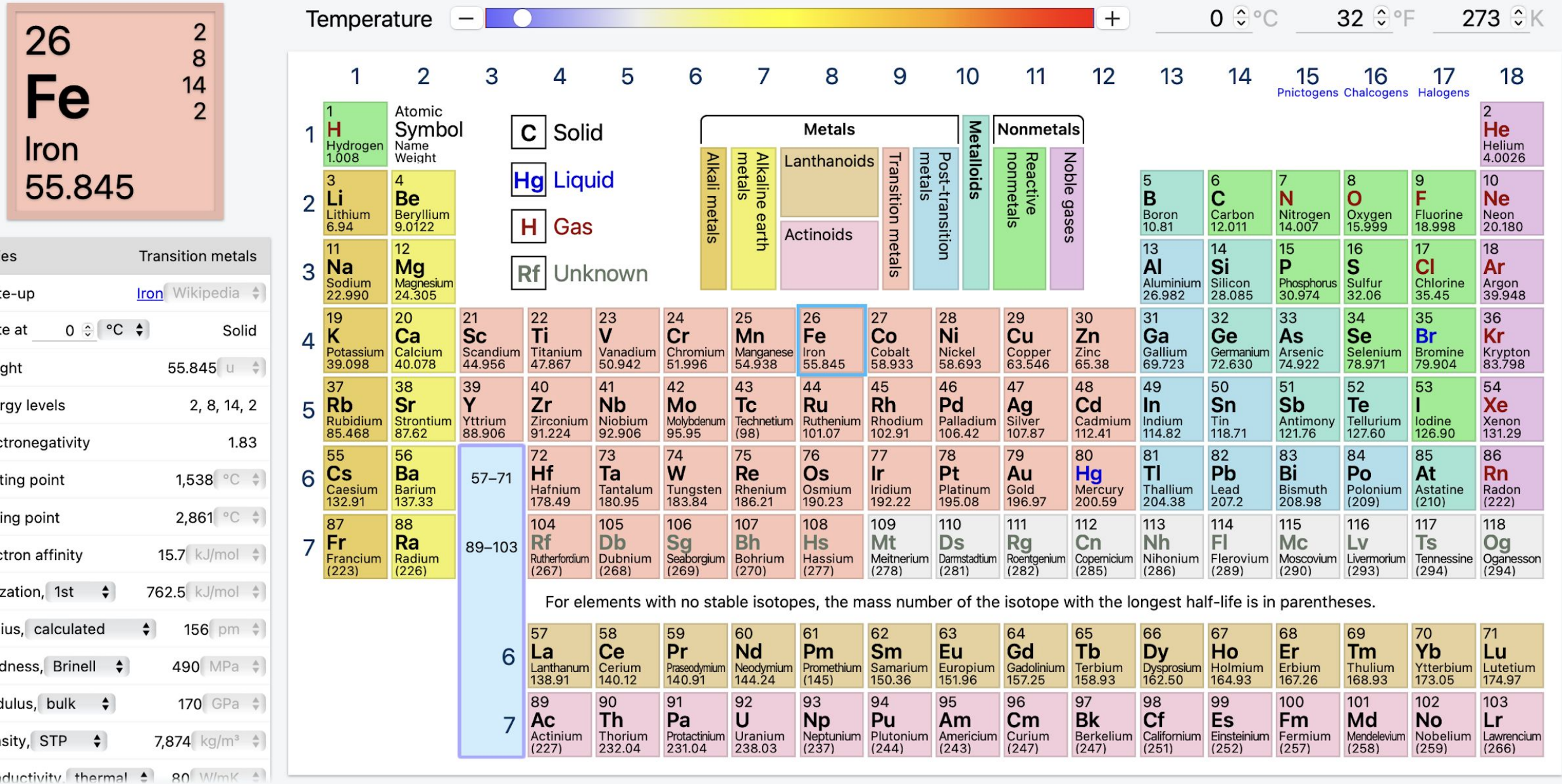
26
Fe
Iron
55.845
2
8
14
2
Temperature
0 °C
32 °F
273 K
Series
Transition metals
Write-up
Iron Wikipedia
State at 0 °C
Solid
Weight
55.845 u
Energy levels
2, 8, 14, 2
Electronegativity
1.83
Melting point
1,538 °C
Boiling point
2,861 °C
Electron affinity
15.7 kJ/mol
Ionization, 1st
762.5 kJ/mol
Radius, calculated
156 pm
Hardness, Brinell
490 MPa
Modulus, bulk
170 GPa
Density, STP
7,874 kg/m³
Conductivity, thermal
80 W/mK
Atomic
Symbol
Name
Weight
C Solid
Hg Liquid
H Gas
Rf Unknown
Metals
Alkali metals
Alkaline earth metals
Lanthanoids
Actinoids
Transition metals
Post-transition metals
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Reactive nonmetals
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For elements with no stable isotopes, the mass number of the isotope with the longest half-life is in parentheses.

الكتلة الجزيئية = مجموع الكتل الذرية للعناصر في المركب

Molar Mass (Molecular weight M_w): M_w

The sum of atomic weights of 1 mol of the molecule

الكتلة الجزيئية لـ H_2O = عدد الذرات H × 2 + عدد الذرات O × 1

$M_w(H_2O) = 2 \times A_w(H) + A_w(O) = 2 \times 1.008 + 15.999$

M_w of 1 mol of H_2O = 2 (A_w of H) + A_w of O

= (2× 1.008) + 16

= 18.02 g/mol

= 18.02 g/mol

$NaCl = A_w(Na) + A_w(Cl)$

$22.99 + 35.45 = 58.44$ g/mol

What are the molecular weights of the following:

g/mol

$M_w(C_2H_6) = 2 \times Aw(C) + 6 \times Aw(H) = 2 \times 12.01 + 6 \times 1.008 = 30.07$

$N_2O_4 = 2\,Aw(N) + 4 \times Aw(O) = 2 \times 14.01 + 4 \times 16 = 92.02$ g/mol

$C_8H_{18}O_4N_2S = 8\,Aw(C) + 18\,Aw(H) + 4\,Aw(O) + 2\,Aw(N) + Aw(S)$

$= 8 \times 12.01 + 18 \times 1.008 + 4 \times 16 + 2 \times 14.01 + 32.06$

$= 238.38$ g/mol

$Al_2(CO_3)_3 = 2\,Aw(Al) + (Aw(C) + 3\,Aw(O)) \times 3$

$= 2 \times 26.98 + (12.01 + 3 \times 16) \times 3 = 233.99$

$MgSO_4.7H_2O = Aw(Mg) + Aw(S) + 4 \times Aw(O) + 7(2Aw(H) + Aw(O))$

$= 24.31 + 32.06 + 4 \times 16 + 7(2 \times 1.008 + 16) = 246.489$ g/mol

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عدد المولات

Number of moles (n)

$$n = \frac{wt(g)}{Mw(g/mol)}$$

عدد المولات = الكتلة المعطاة / الكتلة الجزيئية

Remember: No. of particles = No. of moles × Avogadro's number

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$n = \frac{W_t}{M_w} = \frac{6.07}{}$

Example

Methane (CH_4) is the principal component of the natural gas. How many moles of methane are present in 6.07 g of CH_4? ما عدد المولات الموجوده في كتله 6.07g من الميثان

M_w of CH_4 = 12.01 + (4× 1.008) = 16.04 g/mol

M_w = 16.04 g/mol

① الخطوه الاولى حساب الكتله الجزيئيه CH_4

$M_w = A_w(C) + 4A_w(H) = 12.01 + 4 \times 1.008$

$= 16.04$ g/mol

n of CH_4 = 6.07 $g_{(CH4)}$ × $\left(\frac{1 mol_{(CH4)}}{16.04\ g_{(CH4)}}\right)$ = 0.378 $mol_{(CH4)}$

$n = \frac{W_t}{M_w} = \frac{6.07}{16.04} = 0.378$ mol

② تطبيق قانون عدد المولات

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$n = \frac{Wt}{Mw}$ $Wt = n \times Mw$

Learning check

What is the number of moles in 21.5 g $CaCO_3$?

$Mw = Aw(Ca) + Aw(C) + 3 \times Aw(O)$

$= 40.08 + 12.01 + 3 \times 16$

$Mw = 100.09$ g/mol

$n = \frac{Wt}{Mw} = \frac{21.5}{100.09}$

$= 0.215$ mol

What is the mass in grams of 0.6 mol C_4H_{10}?

$Mw = 4\,Aw(C) + 10\,Aw(H)$

$= 4 \times 12.01 + 10 \times 1.008$

$= 58.12$

$Wt = n \times Mm$

$= 0.6 \times 58.12 = 34.87$ g

How many atoms of Cu are present in 35.4 g of Cu?

① تحويل الكتلة الى عدد مولات

$n = \frac{Wt}{Aw} = \frac{35.4}{63.55} = 0.557$ mol

تحويل عدد المولات الى عدد جسيمات

عدد الجزيئات = عدد المولات × عدد أفوكادرو

number of atoms $= 0.557 \times 6.022 \times 10^{23} = 3.35 \times 10^{23}$ atom

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Percent Composition of Compounds

حساب النسبه الوزنيه لعنصر في المركب

Mass percent (weight percent) of each element in a compound.

حساب نسبه كتله كل عنصر في المركب = $\frac{n \times \text{الكتله الذريه}}{\text{الكتله الجزيئيه}} \times 100\%$

$$\%x = \frac{n \times A_w(x)}{Mw} \times 100$$

n is number of atoms of each element in the compound

n عدد مولات كل عنصر في المركب

Example

Calculate the mass percent of each element in ethanol (C_2H_5OH) ?

احسب نسبه كل عنصر فى هذا المركب

$$\%x = \frac{n \times A_w(x)}{Mw} \times 100$$

الحلول حساب نسبه الكربون والكسجين والهيدروجين

① حساب الكتله الجزيئيه للمركب

$Mw = 2(12.01) + 6 \times 1.008 + 16 = 46.07$

Mass of 1 mol (molar mass) of C_2H_5OH = 24.02+6.048+16.00= 46.07 g/mol

$$568.762 = 5.68762 \times 10^2 \ (6\ SF)$$

$$C\% = \frac{2 \times 12.01}{46.07} \times 100\% = 52.14\%$$

$$H\% = \frac{6 \times 1.008}{46.07} \times 100\% = 13.13\%$$

$$O\% = \frac{16}{46.07} \times 100\% = 34.73\%$$

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نسبه التركيب

Percent composition

:Determining the Formula of a Compound

الصيغه الاوليه

empirical formula

ابسط نسبه بين الذرات

CH_2O

الصيغه الجزيئيه

molecular formula

وضاعفات صحيحه من الصيغ الاوليه

$C_6H_{12}O_6$

$$0.00000772 = 7.72 \times 10^{-6} \text{ (3 SF)}$$

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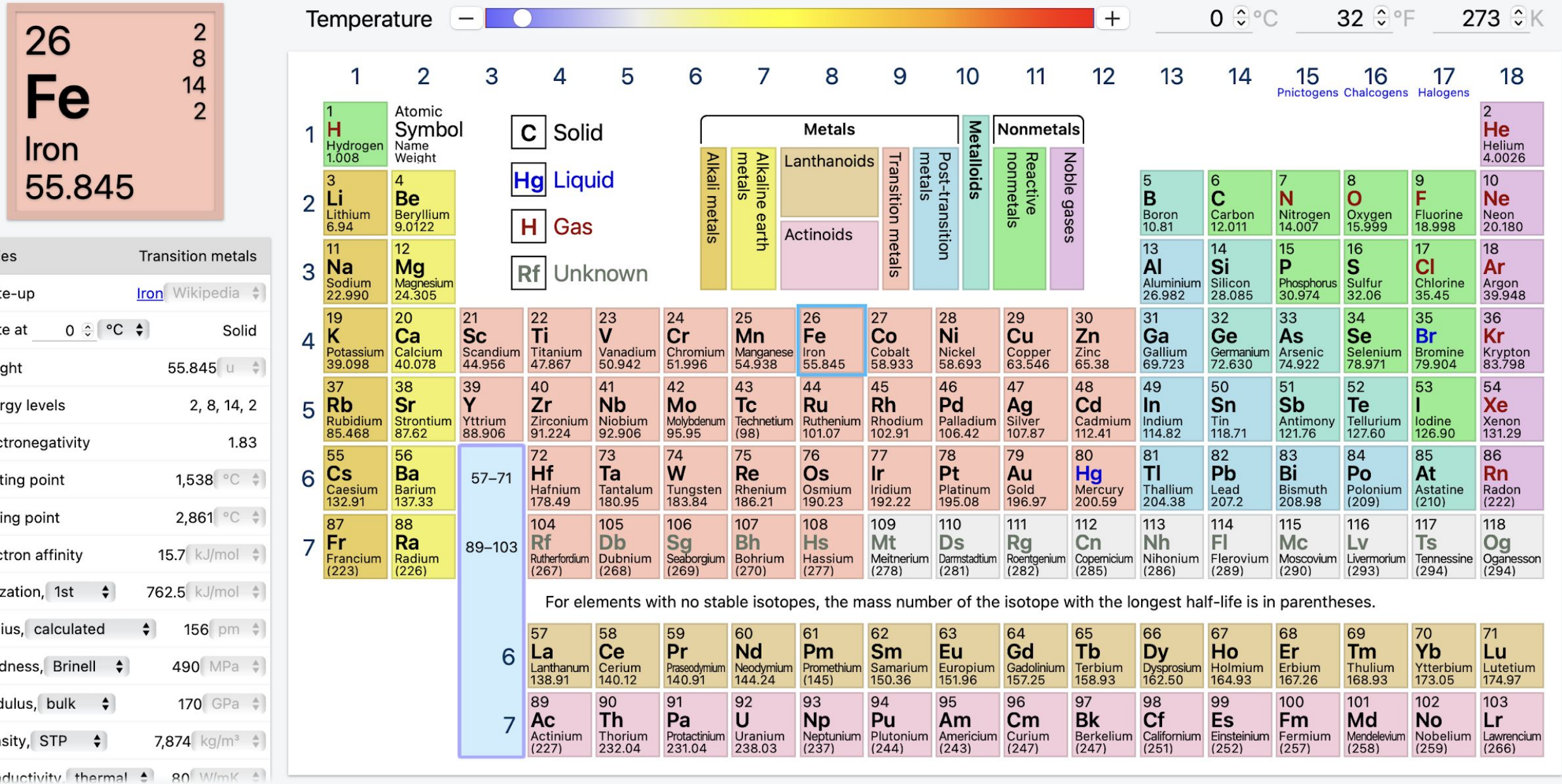
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Conductivity, thermal
80 W/mK
Atomic
Symbol
Name
Weight
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Hg Liquid
H Gas
Rf Unknown
Metals
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Alkaline earth metals
Lanthanoids
Actinoids
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Post-transition metals
Metalloids
Nonmetals
Reactive nonmetals
Noble gases
Pnictogens
Chalcogens
Halogens
For elements with no stable isotopes, the mass number of the isotope with the longest half-life is in parentheses.

$W_t = 0.2154 \times 10^3$

Question 1

$= 215.4\ g$

Determine the number of moles of aluminum in 0.2154 kg of Al.

A) 1.297 x 1023 mol
B) 5.811 x 103 mol
C) 7.984 mol
D) 0.1253 mol
E) 7.984 x 10-3 mol

$n = \frac{W_t}{M_W} = \frac{215.4}{26.98}$

$= 7.984$ mol

Question 2

How many phosphorus atoms are there in 2.57 g of P?

A) 4.79 x 1025
B) 1.55 x 1024
C) 5.00 x 10^{22}
D) 8.30 x 10-2
E) 2.57

① $n = \frac{W_t}{M_W} = \frac{2.57}{30.97} = 0.08298$

② atoms $= n \times N_A = 0.08298 \times 6.022 \times 10^{23}$

5×10^{22}

H_2 molecules

Question 3

One mole of H2

A) contains 6.0 x 10^{23} H atoms
B) contains 6.0 x 10^{23} H_2 molecules
C) contains 1 g of H_2
D) is equivalent to 6.02 x 10^{23} g of H_2
E) None of the above

6.022×10^{23}

Question 4

How many oxygen atoms are present in 5.2 g of O2?

A) 5.4 x 10-25 atoms
B) 9.8 x 1022 atoms
C) 2.0 x 10^{23} atoms
D) 3.1 x 1024 atoms
E) 6.3 x 1024 atoms

$M_W = 2\ A_W(O) = 2 \times 16 = 32$

① $n = \frac{W_t}{M_W} = \frac{5.2}{32} = 0.1625$ mole

② molecules $= n \times N_A = 0.1625 \times 6.022 \times 10^{23}$

$= 9.785 \times 10^{22}$

③ atom $= 9.785 \times 10^{22} \times 2 = 2 \times 10^{23}$

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33 S 16

33-16=17

Question 5

How many protons and neutrons are in sulfur-33?

A) 2 protons, 16 neutrons

B) 16 protons, 31 neutrons

C) 16 protons, 17 neutrons

D) 15 protons, 16 neutrons

Question 6

What is the mass of 5.45 x 10-3 mol of glucose, C6 H12O6?

A) 0.158 g
B) 982 g
C) 3.31 x 104 g
D) 0.982 g
E) None of the above.

$M_W = 6\times12.01 + 12\times1.008 + 6\times16$

$M_W = 180.156$ g/mol

$W_t = n \times M_W = 5.45\times10^{-3}\times180.156 = 0.982$

Question 7

Determine the mass percent of iron in Fe4[Fe(CN)6] 3.

A) 45% Fe
B) 26% Fe
C) 33% Fe
D) 58% Fe
E) None of the above.

Fe

7 ذرات الحديد

18 ذرات الكربون

18 ذرات N

$MW = 7Aw(Fe) + 18Aw(C) + 18(Aw\,N)$

$M_w = 7\times55.85 + 18\times12.01 + 18\times14.01$

$= 859.31$

$$Fe\% = \frac{n \times Aw}{Mw} \times 100\%$$

$$= \frac{7\times55.85}{859.31}\times100 = 45.49\%$$

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كلية العلوم التطبيقية
Faculty of Applied Sciences

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Chemical reaction and chemical equation

Chapter 4

COURSE NAME: CHEMISTRY 101
COURSE CODE: 402101-4

Chemical Reactions

تفاعل كيميائي

Reactants → **Products**

متفاعلات — نواتج

A process in which one or more substances is changed into one or more new substances

عملية يحدث فيها تغير لمادة او اكثر لانتاج مادة او اكثر

$2H_2\,(g) + O_2\,(g) \rightarrow 2H_2O\,(l)$

تفاعل 2 مول من غاز H_2 مع مول واحد من غاز O_2 لانتاج 2 مول H_2O

$2HgO\,(s) \rightarrow 2Hg\,(l) + O_2\,(g)$

2 مول من اكسيد الزئبق الصلب يتحول الى 2 مول زئبق سائل و مول من الاكسجين

g غاز
l سائل
s صلب
aq محلول

Chemical Equations

المعادله الكيميائيه تعبير عملي لتفاعل الكيميائي وفيه

.It is a way to represent the chemical reaction

:It shows us

١- رموز المتفاعلات و النواتج

- The chemical symbols of reactants and products
- The physical states of reactants and products– (s), (l), (g), (aq)
- Balanced equation (same number of atoms on each side)

٢. الحاله الفيزيائيه

٣. معادله موزنة (لنفس عدد الذرات في كل طرف)

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

4 ذرات هيدروجين
2 ذرة O

H ذرة 4
O ذرة 2

Reactants (starting materials) — Products (materials formed)

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وزن المعادله الكيميائيه

Balancing Chemical Equations

The number of atoms of each element must be the same on both sides of the equation.

$$2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O \qquad C_2H_6 + 7/2O_2 \rightarrow 2CO_2 + 3H_2O$$

$$2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$$

Reactants	Products
4 C	4 C
12 H	12 H
14 O	14 O

Reactants	Products
4 C	4 C
12 H	12 H
14 O	14 O

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Balance the following equations:

(a) $2C + O_2 \longrightarrow 2CO$

(b) $2CO + O_2 \longrightarrow 2CO_2$

(c) $H_2 + Br_2 \longrightarrow 2HBr$

(d) $2K + 2H_2O \longrightarrow 2KOH + H_2$

(e) $2Mg + O_2 \longrightarrow 2MgO$

(f) $2O_3 \longrightarrow 3O_2$

(g) $2H_2O_2 \longrightarrow 2H_2O + O_2$

(h) $N_2 + 3H_2 \longrightarrow 2NH_3$

(i) $Zn + 2AgCl \longrightarrow ZnCl_2 + 2Ag$

(j) $S_8 + 8O_2 \longrightarrow 8SO_2$

Stoichiometry

The quantitative study of reactants and products in a chemical reaction

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

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The Mole Method:

Stoichiometric coefficients in a chemical equation can be interpreted as the number of moles of each substance.

$$N_2\,(g) + 3\,H_2\,(g) \rightarrow 2NH_3\,(g)$$

N_2	1 mole 6.022×10^{23} molecules
H_2	3 mole $3 \times 6.022 \times 10^{23}$ molecules
NH_3	2 mole $2 \times 6.022 \times 10^{23}$ molecules

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Mole Ratios

$$N_2\,(g) + 3\,H_2\,(g) \rightarrow 2NH_3\,(g)$$

Recall that the coefficient on N_2 is 1 but is not explicitly written in the reaction Coefficients:

$N_2 = 1$
$H_2 = 3$
$NH_3 = 2$

نسب اكولية

Using the coefficients we can write <u>mole ratios</u>

<u>Definition:</u> mole ratio gives the relative amounts of reactants and products

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Mole Ratios

$$N_2\,(g) + 3\,H_2\,(g) \rightarrow 2NH_3\,(g)$$

- For each 1 mole of N_2, 3 moles of H_2 are required.

$$\frac{1\,mol\,N_2}{3\,mol\,H_2}$$

- For each 1 mole of N_2, 2 moles of NH_3 will be produced

$$\frac{1\,mol\,N_2}{2\,mol\,NH_3}$$

- For 3 moles of H_2, 2 moles of NH_3 will be produced

$$\frac{3\,mol\,H_2}{2\,mol\,NH_3}$$

MOLE to MOLE Stoichiometry

$N_2\ (g) + 3\ H_2\ (g) \rightarrow 2NH_3\ (g)$

- If you are given 6 moles of H_2, how many moles of N_2 do you need?

$$\frac{6\ mol\ H_2}{} * \frac{1\ mol\ N_2}{3\ mol\ H_2} = 2\ mol\ N_2$$

- If you are given 0.5 moles of H_2, how many moles of N_2 do you need?

$$\frac{0.5\ mol\ H_2}{} * \frac{1\ mol\ N_2}{3\ mol\ H_2} = 0.2\ mol\ N_2$$

- You can flip the mole ratios around if you are asked the following: If you are given 4 moles of N_2, how many moles of H_2 do you need?

$$\frac{4\ mol\ N_2}{} * \frac{3\ mol\ H_2}{1\ mol\ N_2} = 12\ mol\ H_2$$

- Use the same method for finding the amount of product that will be produced. Given 6 moles of H_2, how much NH_3 will be made?

$$\frac{6\ mol\ H_2}{} * \frac{2\ mol\ NH_3}{3\ mol\ H_2} = 4\ mol\ NH_3$$

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Example

Silicon tetrachloride ($SiCl_4$) can be prepared by heating Si in chlorine gas:

$$1Si\,(s) + 2Cl_2\,(g) \rightarrow 1SiCl_4\,(l)$$

In one reaction, 0.507 mole of $SiCl_4$ is produced. How many moles of molecular chlorine were used in the reaction?

Cl_2	$SiCl_4$
2 mol	1 mol
??	0.507 mol

$0.507 \text{ moles } SiCl_4 \cdot \frac{2 \text{ moles } Cl_2}{1 \text{ moles } SiCl_4}$

1.01 moles Cl_2

n of Cl_2 used = ($0.507\ mol_{SiCl4} \times (2\ mol_{Cl2} / 1\ mol_{SiCl4}$)

= $1.01\ mol_{Cl2}$

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Example

If 85.0 g of CH_4 is consumed by a person over a certain period, what is the mass of CO_2 produced?

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

Convert 85.0 g to moles:

$n\ (CH_4) = wt/Mw = (85.0/16.04) = 5.30\ mol_{(CH4)}$

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

1 mole of CH_4 — 1 mole of CO_2

5.30 moles — ??

$n\ (CO_2) = 5.30\ mol_{(CH4)} \times (1mol_{(CO2)}/1mol_{(CH4)}) = 5.30\ mol_{(CO2)}$

$wt\ (CO_2) = n \times Mw = 5.30\ mol_{(CO2)} \times (44.01g_{(CO2)} / 1mol_{(CO2)})$

$= 233.2\ g = 2.33 \times 10^2\ g_{(CO2)}$

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Question 1

When it is correctly balanced, the correct coefficients for the equation below are

$PCl_3 + H_2O$ ----> $H_3PO_3 + HCl$

A) 1, 3, 1, 1
B) 1, 3, 1, 3
C) 1, 1, 1, 3
D) 2, 3, 2, 3

P	1	1
Cl	3	3
H	6	6
O	3	3

Question 2

What mass of copper(II) nitrate would be produced from the complete reaction of 45.6 g of copper, according to the chemical reaction shown below?

$Cu + 2AgNO_3 \longrightarrow Cu(NO_3)_2 + 2Ag$

A) 0.72 g
B) 21.1 g
C) 98.7 g
D) 135 g
E) 187 g

63.55 + 2X14 + 6X16 = 187.6

Cu → $Cu(NO_3)_2$

moles → moles

$n = \frac{45.6}{63.55} = 0.72$

0.72 moles

$W_t = n \times M_w = 0.72 \times 187.6 = 134.7\,g$

mass Cu = 45.6 → mass

Question 3

Calculate the number of moles of H_2O formed when 0.200 mole of $Ba(OH)_2$ is treated with 0.500 mol of $HClO_3$ according to the chemical reaction shown below.

$Ba(OH)_2 + 2HClO_3$ ----> $Ba(ClO_3)_2 + 2\,H_2O$

A) 1.00 mol
B) 0.600 mol
C) 0.500 mol
D) 0.400 mol
E) 0.200 mol

0.2 mole $Ba(OH)_2$ • 2 H_2O / 1 $Ba(OH)_2$

0.4 moles

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Question 4

What is the coefficient for CO2 when the following chemical equation is properly balanced using the smallest set of whole numbers?

$2C_4H_{10} + 13O_2 \text{ ----> } 8CO_2 + 10H_2O$

A) 1
B) 4
C) 6
D) 8
E) 12

Question 5

When it is correctly balanced, the correct coefficients for the equation below are

$PCl_3 + H_2O$ ----> $H_3PO_3 + HCl$

A) 1, 3, 1, 1
B) 1, 3, 1, 3
C) 1, 1, 1, 3
D) 2, 3, 2, 3

Question 6

What mass of copper(II) nitrate would be produced from the complete reaction of 45.6 g of copper, according to the chemical reaction shown below?

$Cu + 2AgNO_3 \longrightarrow Cu(NO_3)_2 + 2Ag$

A) 0.72 g
B) 21.1 g
C) 98.7 g
D) 135 g
E) 187 g

Question 7

Calculate the number of moles of H_2O formed when 0.200 mole of $Ba(OH)_2$ is treated with 0.500 mol of $HClO_3$ according to the chemical reaction shown below.

$Ba(OH)_2 + 2HClO_3$ ----> $Ba(ClO_3)_2 + 2\ H_2O$

A) 1.00 mol
B) 0.600 mol
C) 0.500 mol
D) 0.400 mol
E) 0.200 mol

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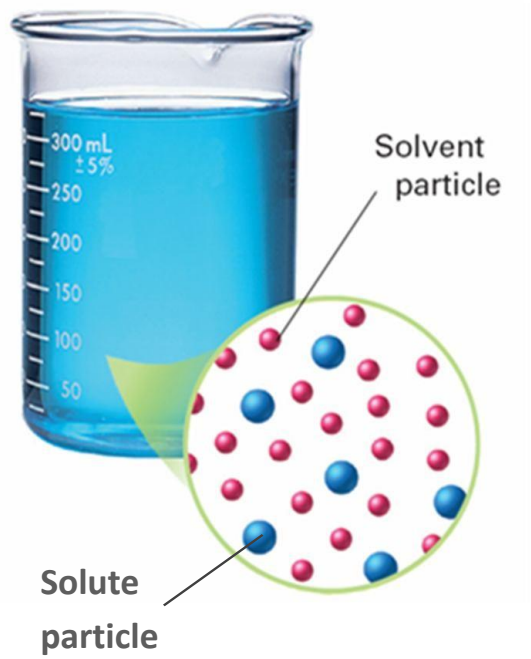
Chemical Reactions in Solutions & Concentrations

Chapter 5

COURSE NAME: CHEMISTRY 101
COURSE CODE: 402101-4

Solutions



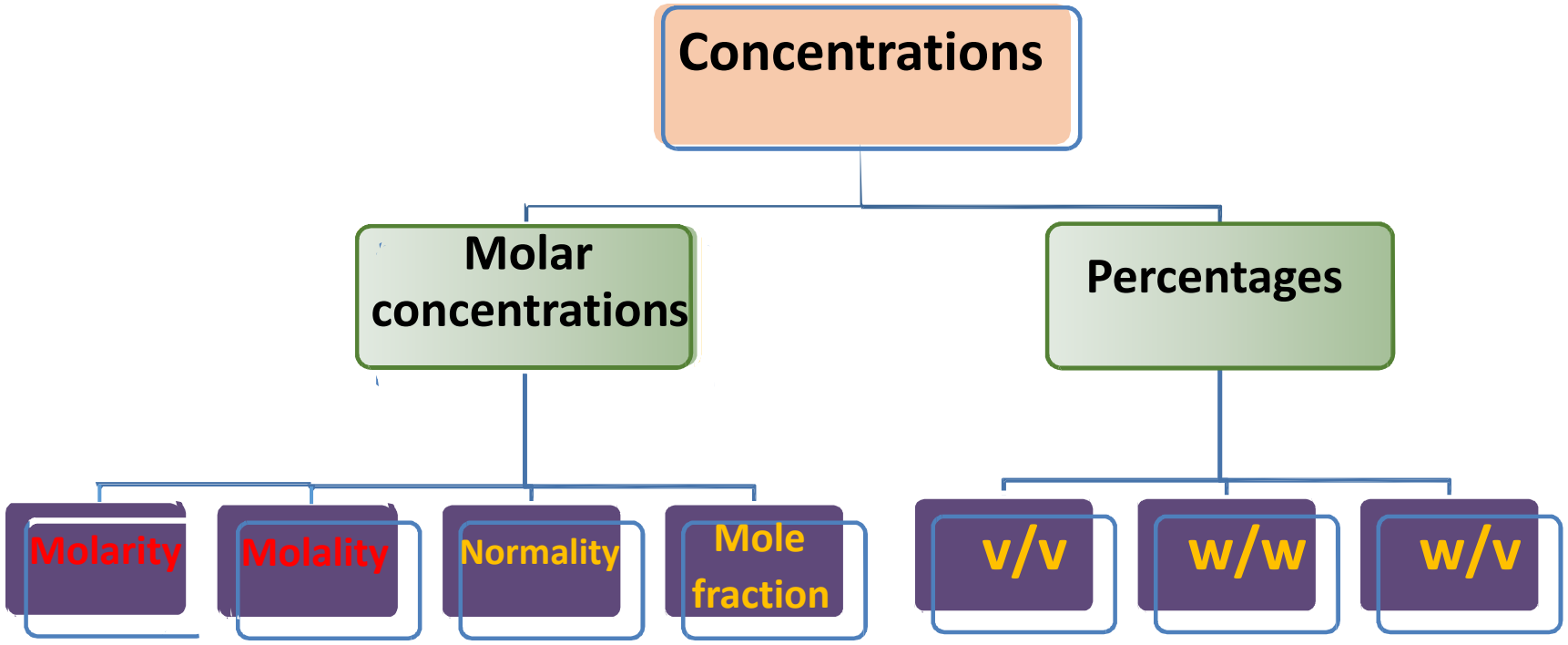
Solution: a homogeneous mixture of two or more substances

Solute: a substance that is being dissolved (smaller amount)

Solvent: a substance which dissolves a solute (larger amount)

Concentrations

The ***concentration*** of a solution is the amount of solute present in a given quantity of a solvent or solution.



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Molarity

The number of moles of solute dissolved in one liter of solution.

$$\text{Molarity } (M) = \frac{\text{moles of solute}}{\text{liters of solution}}$$

What is the unit of molarity?
What is the relationship between weight and molarity?

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Example

A solution has a volume of 2.0 L and contains 36.0 g of glucose ($C_6H_{12}O_6$). If the molar mass of glucose is 180 g/mol, what is the molarity of the solution?

No. of mol of glucose = wt (g) / Mw (g/mol) = 36.0 g/ 180 g/mol = 0.2 mol

M = n (mol) / V (L) = 0.2 mol /2.0 L = 0.1 mol/L

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Molality

The number of moles of solute dissolved in one kilogram of solvent

Molality ***(m)***

$$m = \frac{\text{moles of solute}}{\text{mass of solvent (kg)}}$$

Molarity ***(M)***

$$M = \frac{\text{moles of solute}}{\text{liters of solution}}$$

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Example

What is the molality of a 5.86 *M* ethanol (C_2H_5OH) solution whose density is 0.927 g/mL?

$$m = \frac{\text{moles of solute}}{\text{mass of solvent (kg)}}$$

Assume 1 L of solution:

5.86 moles ethanol = 270 g ethanol

927 g of solution (1000 mL x 0.927 g/mL)

mass of solvent = mass of solution – mass of solute

= 927 g – 270 g = 657 g = 0.657 kg

$$m = \frac{\text{moles of solute}}{\text{mass of solvent (kg)}} = \frac{5.86 \text{ moles } C_2H_5OH}{0.657 \text{ kg solvent}} = 8.92\ m$$

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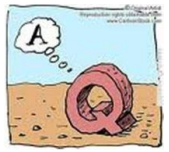
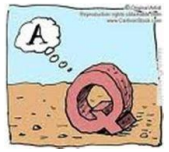
Learning check

What is the concentration of a solution in mol/L when 80 g of calcium carbonate, $CaCO_3$, is dissolved in 2 L of solution?



How many liters of 0.25 M NaCl solution must be measured to obtain 0.1 mol of NaCl?



A student needs to prepare 250 ml of 0.1 M of $Cd(NO_3)_2$ solution. How many grams of cadmium nitrate are required?

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Type of Chemical Reactions in Aqueous Solutions

1) Acid-Base Reactions

2) Oxidation-Reduction Reactions

3) Precipitation Reactions

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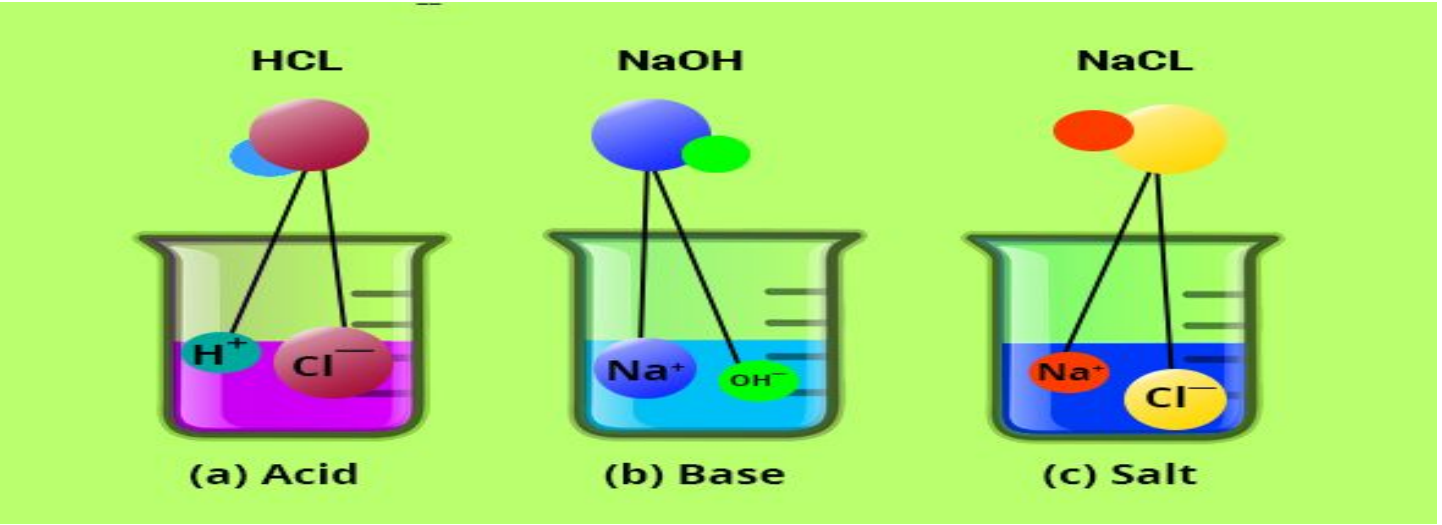
I. Acid-Base Reactions

acid + base ⟶ salt + water

$HCl\ (aq) + NaOH\ (aq) \longrightarrow NaCl\ (aq) + H_2O\ (l)$



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II. Oxidation-Reduction Reactions

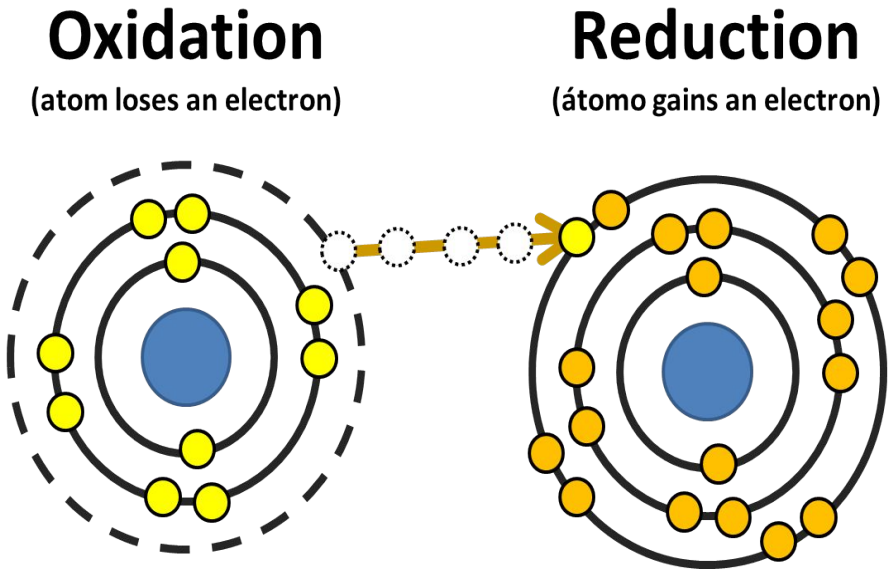
Redox reactions are electron transfer reactions

$Mg + 2Ag^{+} \rightarrow Mg^{2+} + 2Ag$

Half-reactions:

$Mg\ (s) \rightarrow Mg^{2+} + 2e$

$2Ag^{+} + 2e \rightarrow 2Ag$



Oxidation Reactions : half-reaction that involves a loss of electrons

Reduction Reactions : half-reaction that involves a gain of electrons

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III. Precipitation Reactions

A precipitate is an insoluble solid that separates from the solutions

$$Pb(NO_3)_2\,(aq) + 2KI\,(aq) \longrightarrow PbI_2\,(s) + 2KNO_3\,(aq)$$

$$Pb^{2+}\,(aq) + 2NO_3^-\,(aq) + 2K^+\,(aq) + 2I^-\,(aq) \longrightarrow PbI_2\,(s) + 2K^+\,(aq) + 2NO_3^-\,(aq)$$

$$Pb^{2+}\,(aq) + 2I^-\,(aq) \longrightarrow PbI_2\,(s)$$

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Question 1

Molarity is the number of …… of solute dissolved

Solution

a) Grams

b) Milliliter

c) Second

d) moles

Question 2

Molality is the number of moles of ……. dissolved in 1kg solvent

a) Solvent
b) Solute
c) Solution
d) acid

Question 3

Molarity is the number of moles of solute dissolved

1 …… of the Solution

a) Grams

b) Liter

c) Second

d) moles

Question 4

A solution has a volume of 2.0 L and contains 36.0 g of glucose ($C_6H_{12}O_6$). If the molar mass of glucose is 180 g/mol, what is the molarity of the solution

a) 1.0
b) 1.00
c) 0.1
d) 0.01

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Question 5

How many liters of 0.25 M NaCl solution must be measured to obtain 0.1 mol of NaCl

A) 1

B) 2

C) 2.5

D) 3.5

Question 6

What is the concentration of a solution in mol/L when 80 g of calcium carbonate, $Ca(CO_{3)2}$, is dissolved in 2 L of solution? (Molecular weight of Ca(CO3)2 = 100g/mol

A) 0.4
B) 4
C) 0.004
D) 1

Question 7

A student needs to prepare 250 ml of 0.1 M of $Cd(NO_3)_2$ solution. How many grams of cadmium nitrate are required?

(Molecular weight of $Cd(NO_3)_2$ = 236 g/mol

A) 5.9
B) 5.1
C) 5.4
D) 5.6

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Chemical Equilibrium

Chapter
6

COURSE NAME: CHEMISTRY 101
COURSE CODE: 402101-4

Equilibrium

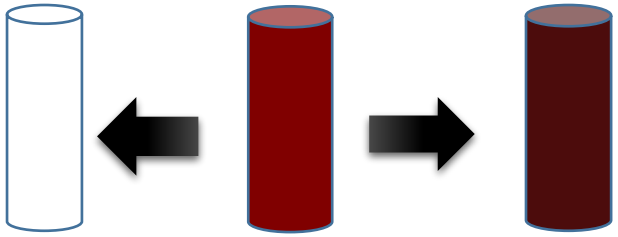
Equilibrium is a state in which there are no observable changes as time goes by

Chemical equilibrium is achieved when:

- the rates of the forward and reverse reactions are equal and
- the concentrations of the reactants and products remain constant

Chemical equilibrium

$N_2O_4\ (g) \rightleftharpoons 2NO_2\ (g)$



N_2O_4 Colorless — Equilibrium state — NO_2 Dark-brown

Physical equilibrium

$H_2O\ (l) \rightleftharpoons H_2O\ (g)$

Physical equilibrium is between two states of the same substance

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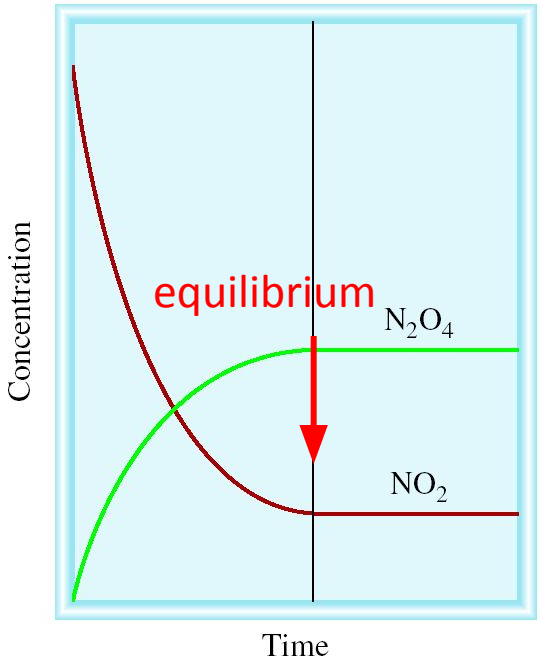
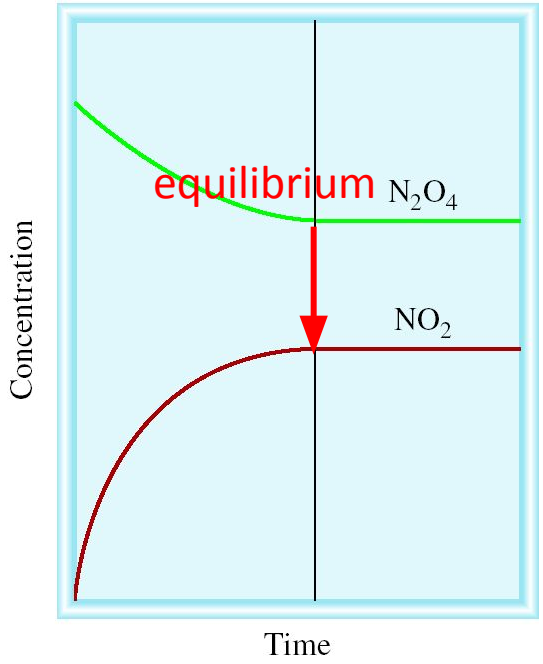
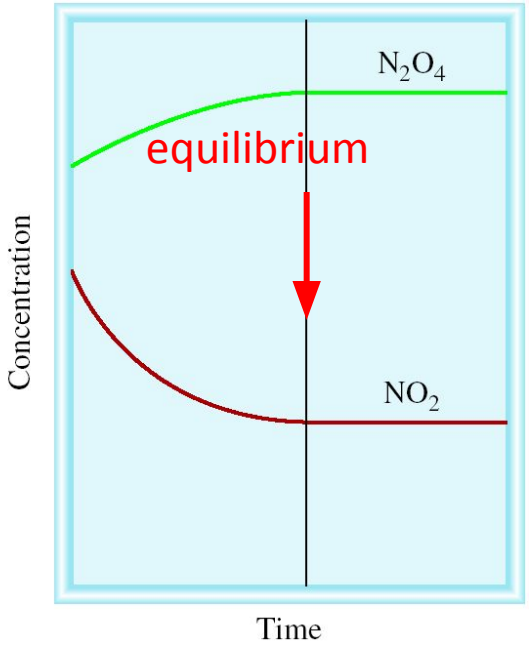
$$N_2O_4\,(g) \rightleftharpoons 2NO_2\,(g)$$



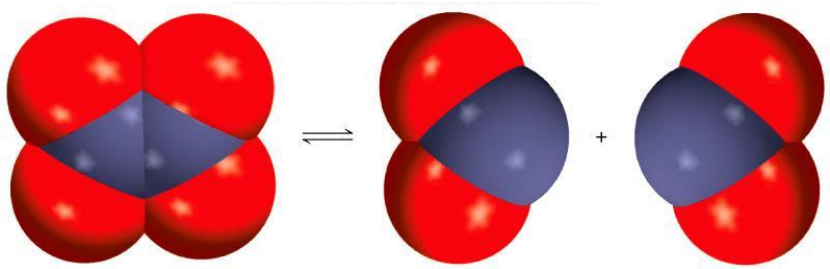
Start with NO_2



Start with N_2O_4



Start with NO_2 & N_2O_4



Equilibrium Constant K

$$N_2O_4\,(g) \rightleftharpoons 2NO_2\,(g)$$

$$K_c = \frac{[NO_2]^2}{[N_2O_4]} \qquad K_p = \frac{P_{NO_2}^{\,2}}{P_{N_2O_4}}$$

$$K = \frac{[NO_2]^2}{[N_2O_4]} = 4.63 \times 10^{-3}$$

$$aA + bB \rightleftharpoons cC + dD$$

$$K = \frac{[C]^c[D]^d}{[A]^a[B]^b}$$

Law of Mass Action

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Equilibrium Position

K>>1

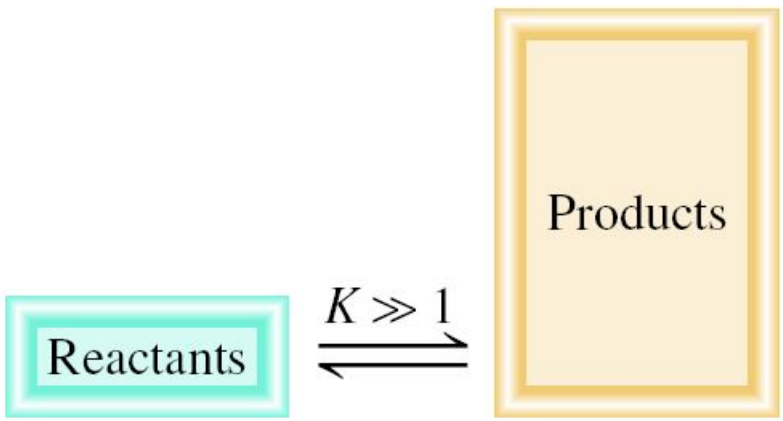
Products are favored at equilibrium

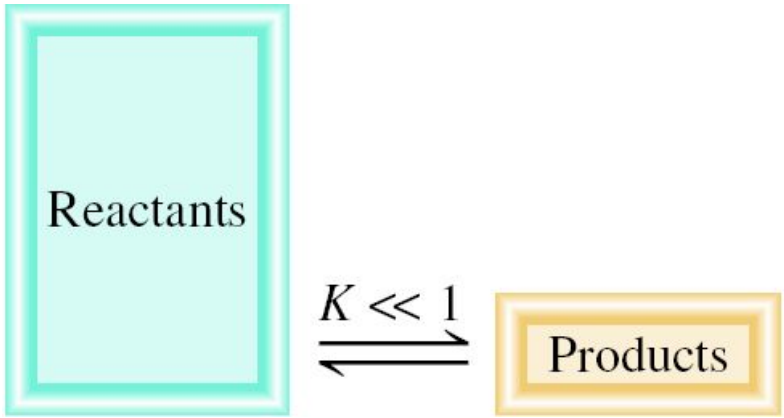
(the equilibrium lie to the right)

K<<1

Reactants are favored at equilibrium

(the equilibrium lie to the left)





Relation between K_c and K_p

$$N_2O_4\,(g) \rightleftharpoons 2NO_2\,(g)$$

$$K_c = \frac{[NO_2]^2}{[N_2O_4]} \qquad K_p = \frac{P^2_{NO_2}}{P_{N_2O_4}}$$

In most cases

$$K_c \neq K_p$$

$$aA\,(g) + bB\,(g) \rightleftharpoons cC\,(g) + dD\,(g)$$

$$K_p = K_c(RT)^{\Delta n}$$

Δn = moles of gaseous products – moles of gaseous reactants

$= (c + d) - (a + b)$

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Homogeneous Equilibrium

Homogenous equilibrium applies to reactions in which all reacting species **are in the same phase.**

$$CH_3COOH(aq) + H_2O(l) \rightleftharpoons CH_3COO^-(aq) + H_3O^+(aq)$$

$$K_c' = \frac{[CH_3COO^-][H_3O^+]}{[CH_3COOH][H_2O]} \qquad [H_2O] = \text{constant}$$

$$K_c = \frac{[CH_3COO^-][H_3O^+]}{[CH_3COOH]} = K_c'[H_2O]$$

General practice **not** to include units for the equilibrium constant.

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The equilibrium concentrations for the reaction between carbon monoxide and molecular chlorine to form $COCl_2$ (*g*) at 74^0C are [CO] = 0.012 *M*, $[Cl_2]$ = 0.054 *M*, and $[COCl_2]$ = 0.14 *M*. Calculate the equilibrium constants K_c and K_p.

$$CO\ (g) + Cl_2\ (g) \rightleftharpoons COCl_2\ (g)$$

$$K_c = \frac{[COCl_2]}{[CO][Cl_2]} = \frac{0.14}{0.012 \times 0.054} = 220$$

$$K_p = K_c(RT)^{\Delta n}$$

$\Delta n = 1 - 2 = -1$ $\qquad$ $R = 0.0821$ $\qquad$ $T = 273 + 74 = 347$ K

$$K_p = 220 \times (0.0821 \times 347)^{-1} = 7.7$$

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The equilibrium constant K_p for the reaction: $2NO_2\,(g) \rightleftharpoons 2NO\,(g) + O_2\,(g)$

is 158 at 1000K. What is the equilibrium pressure of O_2 if the P_{NO2} = 0.400 atm and P_{NO} = 0.270 atm?

$$K_p = \frac{P_{NO}^2 P_{O_2}}{P_{NO_2}^2}$$

$$P_{O_2} = K_p \frac{P_{NO_2}^2}{P_{NO}^2}$$

$$P_{O_2} = 158 \times (0.400)^2/(0.270)^2 = 347 \text{ atm}$$

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Heterogeneous Equilibrium

Heterogenous equilibrium applies to reactions in which reactants and products **are in different phases**

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

$$K_c' = \frac{[CaO][CO_2]}{[CaCO_3]}$$

$[CaCO_3]$ = constant
$[CaO]$ = constant

$$\boldsymbol{K_c = [CO_2]} = K_c' \times \frac{[CaCO_3]}{[CaO]}$$

$$K_p = P_{CO_2}$$

The concentration of **solids** and **pure liquids** are not included in the expression for the equilibrium constant.

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Consider the following equilibrium at 295 K:

$$NH_4HS\ (s) \rightleftharpoons NH_3\ (g) + H_2S\ (g)$$

The partial pressure of each gas is 0.265 atm. Calculate K_p and K_c for the reaction?

$$K_p = P_{NH_3} P_{H_2S} = 0.265 \times 0.265 = 0.0702$$

$$K_p = K_c(RT)^{\Delta n}$$

$$K_c = K_p(RT)^{-\Delta n}$$

$$\Delta n = 2 - 0 = 2 \qquad T = 295\ K$$

$$K_c = 0.0702 \times (0.0821 \times 295)^{-2} = 1.20 \times 10^{-4}$$

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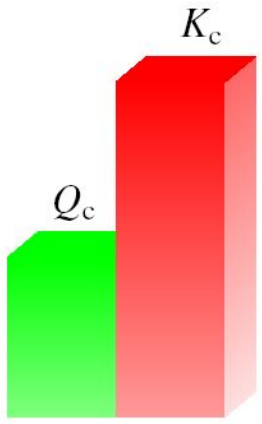
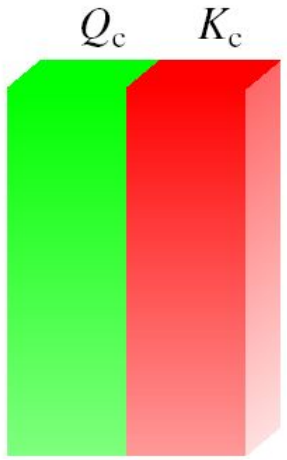
Reaction Quotient Q_c

The ***reaction quotient (Q_c)*** is calculated by substituting the initial concentrations of the reactants and products into the equilibrium constant (K_c) expression.

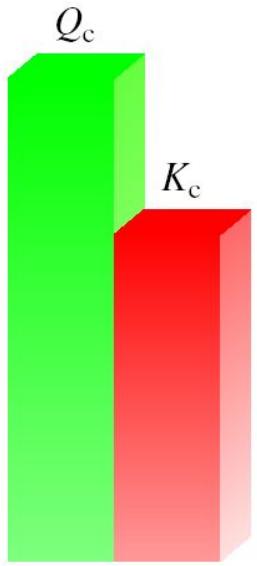
- $Q_c > K_c$ system proceeds to left to reach equilibrium
- $Q_c = K_c$ the system is at equilibrium
- $Q_c < K_c$ system proceeds to right to reach equilibrium



Reactants → Products



Equilibrium : no net change



Reactants ← Products

- Find the value of Q and determine which side of the reaction is favored. Given K_{eq}=0.5

HCl (g) + NaOH (aq) ⇌ NaCl (aq)+ H2O (l)

[HCl]= 3.2 M [NaOH]= 4.3 M[NaCl]=6 M

$$\underset{\text{(2 SF)}}{(8.0 \times 10^4)} \cdot \underset{\text{(3 SF)}}{(5.00 \times 10^2)} = \underset{\text{(2 SF)}}{40 \times 10^6} \quad \text{or} \quad \underset{\text{(2 SF)}}{4.0 \times 10^7}$$

Qc = 0.436 … *Q* is less than K_{eq} so the reaction shifts RIGHT, favors the products.

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Equilibrium Constant Calculations

- **If a reaction can be expressed as the sum of two or more reactions, the equilibrium constant for the overall reaction is given by the product of the equilibrium constants of the individual reactions.**

$$A + B \rightleftharpoons \cancel{C} + \cancel{D} \qquad K'_c$$

$$\cancel{C} + \cancel{D} \rightleftharpoons E + F \qquad K''_c$$

$$A + B \rightleftharpoons E + F \qquad K_c$$

$$K'_c = \frac{[C][D]}{[A][B]} \qquad K''_c = \frac{[E][F]}{[C][D]}$$

$$K_c = \frac{[E][F]}{[A][B]}$$

$$K_c = K'_c \times K''_c$$

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Equilibrium Constant Calculations

- **When the equation for a reversible reaction is written in the opposite direction, the equilibrium constant becomes <u>the reciprocal of the original equilibrium constant</u>.**

$$N_2O_4\,(g) \rightleftharpoons 2NO_2\,(g) \qquad 2NO_2\,(g) \rightleftharpoons N_2O_4\,(g)$$

$$K = \frac{[NO_2]^2}{[N_2O_4]} = 4.63 \times 10^{-3} \qquad K' = \frac{[N_2O_4]}{[NO_2]^2} = \frac{1}{K} = 216$$

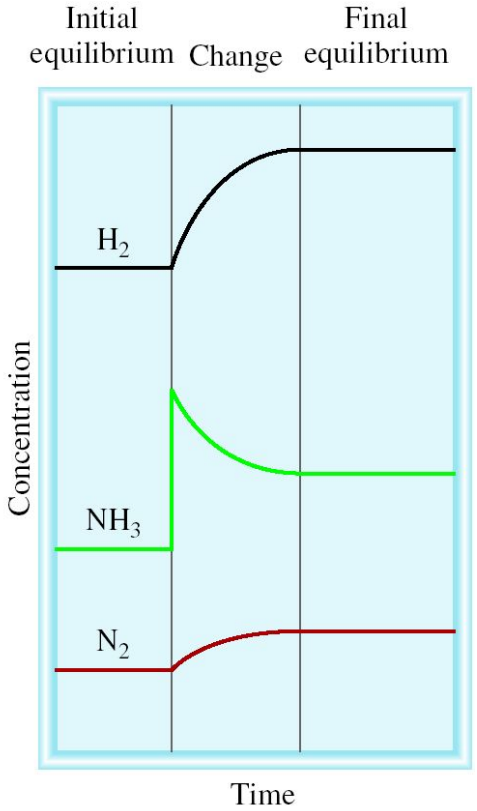
Le Châtelier's Principle

If an external stress is applied to a system at equilibrium, the system adjusts in such a way that the stress is partially offset as the system reaches a new equilibrium position.

I. Changes in Concentration

$$N_2\,(g) + 3H_2\,(g) \rightleftharpoons 2NH_3\,(g)$$

Add NH_3 → Equilibrium shifts left to offset stress



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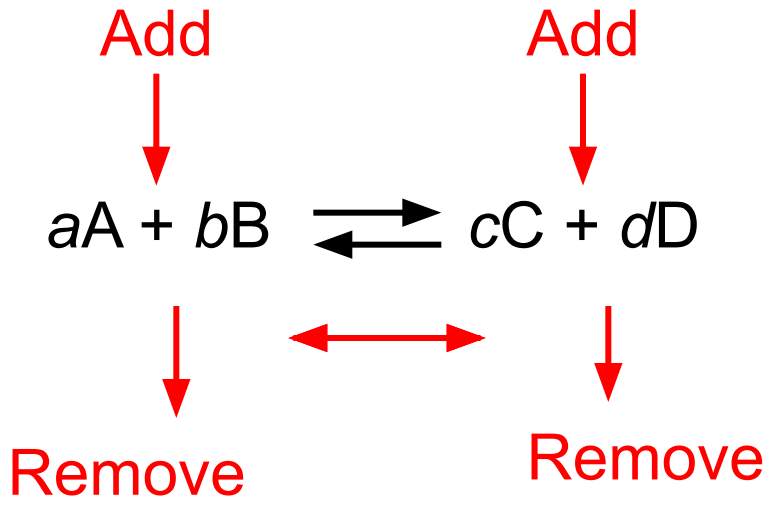
Changes in Concentration continued



Change	Shifts the Equilibrium
Increase concentration of product(s)	left
Decrease concentration of product(s)	right
Increase concentration of reactant(s)	right
Decrease concentration of reactant(s)	left

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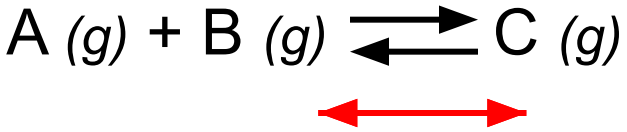
Le Châtelier's Principle

II. Changes in Volume and Pressure



Change	Shifts the Equilibrium
Increase pressure	Side with fewest moles of gas
Decrease pressure	Side with most moles of gas
Increase volume	Side with most moles of gas
Decrease volume	Side with fewest moles of gas

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Le Châtelier's Principle

III. Temperature Changes

- **Consider heat as a product in exothermic reactions**

$$A + B = AB + Heat$$

- **Add heat □ Shift to reactants**
- **Remove heat □ Shift to products**

Consider heat as a reactant in endothermic reactions

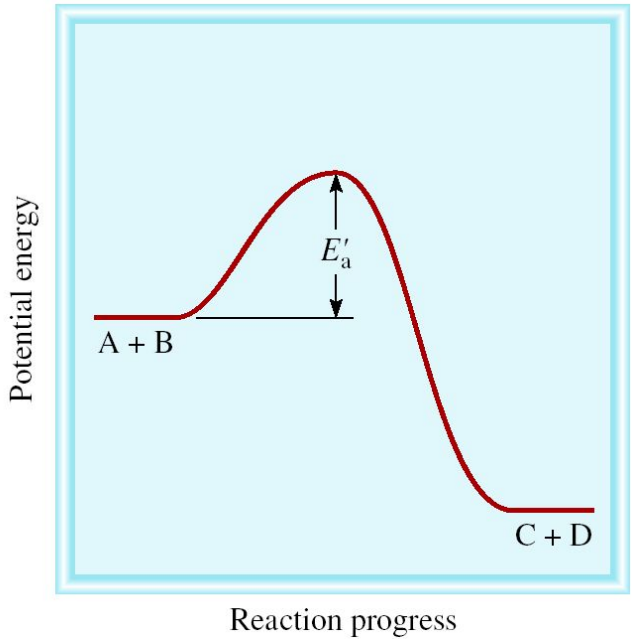
$$A + B + heat = AB$$

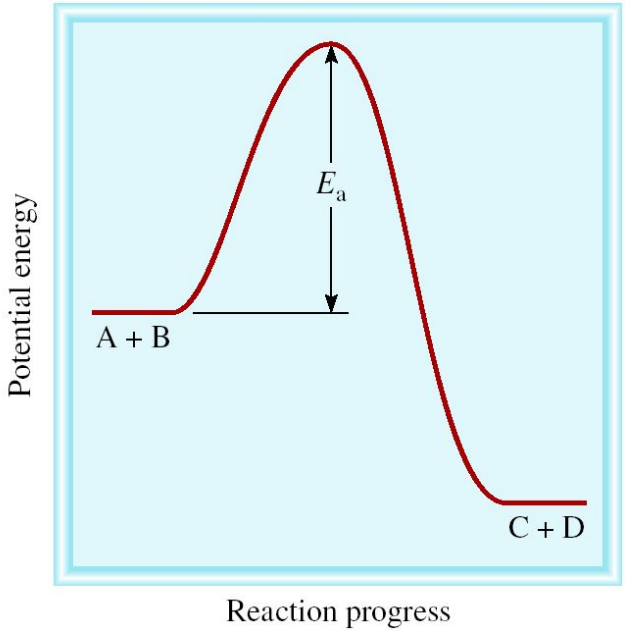
Add heat □ Shift to products

Remove heat □ Shift to reactants

Le Châtelier's Principle

- **Adding a Catalyst**
  - does not change *K*
  - does not shift the position of an equilibrium system
  - system will reach equilibrium sooner





Catalyst lowers E_a for **both** forward and reverse reactions.

Le Châtelier's Principle - Summary

Change	Shift Equilibrium	Change Equilibrium Constant
Concentration	yes	no
Pressure	yes*	no
Volume	yes*	no
Temperature	yes	yes
Catalyst	no	no

*Dependent on relative moles of gaseous reactants and products

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Question 1

Which equilibrium in gaseous phase would be unaffected by an increase in pressure:

(a) $N_2O_4 \rightarrow 2NO_2$
(b) $N_2 + O_2 \rightarrow 2NO$
(c) $N2 + 3H_2 \rightarrow 2NH_3$
(d) $CO + ½\ O_2 \rightarrow O_2 + CO_2$

Question 2

For the equilibrium ,
$2NO_2(g) \rightarrow N_2O_4(g) + 14.6$ kcal
An increase of temperature will:

(a) Favour the formation of N_2O_4
(b) Favour the decomposition of N_2O_4
(c) Not affect the equilibrium
(d) Stop the reaction

Question 3

The equilibrium constant (K_c) for the reaction is
$2SO_3(g) \rightarrow 2SO_2(g) + O_2(g)$
system as described by the above equation is:

(a) $[SO_2]^2/[SO_3]$
(b) $[SO_2]^2[O_2]/[SO_3]^2$
(c) $[SO_3]^2/[SO_3]^2[O_2]$
(d) $[SO_2][O_2]$

Question 4

At equilibrium, _____.

(a) the rates of the forward and reverse reactions are equal
(b) the rate constants of the forward and reverse reactions are equal
(c) all chemical reactions have ceased
(d) the value of the equilibrium constant is 1

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Question 5

The value of Keq for the following reaction is 0.25:
SO_2 (g) + NO_2 (g) -> SO_3 (g) + NO (g)
The value of Keq at the same temperature for the reaction below is _____.
$2SO_2$ (g) + $2NO_2$ (g) -> $2SO_3$ (g) + 2NO (g)

(a) 0.062
(b) 16
(c) 0.25
(d) 0.50

Question 6

Consider the reaction: 2 SO_2(g) + O_2(g) ↔ 2 SO_3(g). If, at equilibrium at a certain temperature, [SO_2] = 1.50 M, [O_2] = 0.120 M, and [SO_3] = 1.25 M, what is the value of the equilibrium constant?

(a) 5.79
(b) 6.94
(c) 8.68
(d) 0.14

Question 7

What is the correct equilibrium constant expression for the following reaction? 2 Cu(s) + O_2(g) ⟶ 2 CuO(s)

(a) Keq = $1/[O_2]^2$
(b) Keq = $[CuO]^2/[Cu]^2[O_2]$
(c) Keq = $[O_2]$
(d) Keq = $1/[O_2]$

Question 8

What is the relationship of the equilibrium constants for the following two reactions?
(1) 2 NO_2(g) ↔ N_2O_4(g); K_1
(2) N_2O_4(g) ↔ 2 NO_2(g) K_2

(a) $K_1 = 1/K_2$
(b) $K_2 = 1/K_1$
(c) $K_1 = K_2$
(d) both a and b are correct

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Question 9

Consider the following endothermic reaction:
$H_2(g) + I_2(g) \leftrightarrow 2\ HI(g)$. If the temperature is increased,

(a) more HI will be produced
(b) some HI will decompose, forming H_2 and I_2
(c) the magnitude of the equilibrium constant will decrease
(d) the pressure in the container will increase

Question 10

Consider the following reaction at equilibrium:
$NO_2(g) + CO(g) \leftrightarrow NO(g) + CO_2(g)$. Suppose the volume of the system is decreased at constant temperature, what change will this cause in the system?

(a) A shift to produce more NO
(b) A shift to produce more CO
(c) A shift to produce more NO_2
(d) No shift will occur

Question 11

Which of these four factors can change the value of the equilibrium constant?

(a) catalyst
(b) pressure
(c) concentration
(d) temperature

Question 12

Which general rule helps predict the shift in direction of an equilibrium reaction?

(a) Le Chatelier's principle
(b) Haber process
(c) Equilibrium constant
(d) Bosch theory

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Acids & Bases: pH Calculations

Chapter 7

COURSE NAME: CHEMISTRY 101
COURSE CODE: 402101-4

Acids & Bases

Definition of acids and bases

Arrhenius concept

Brønsted-Lowry concept

Lewis concept

1- Arrhenius Concept

An acid is a compound that releases H^+ ions in water

A base is a compound that releases OH^- in water.

$$HCl\ (aq) \longrightarrow H^+\ (aq) + Cl^-\ (aq)$$

$$NaOH\ (aq) \longrightarrow Na^+\ (aq) + OH^-\ (aq)$$

Limitations: Some bases do not contain OH^-

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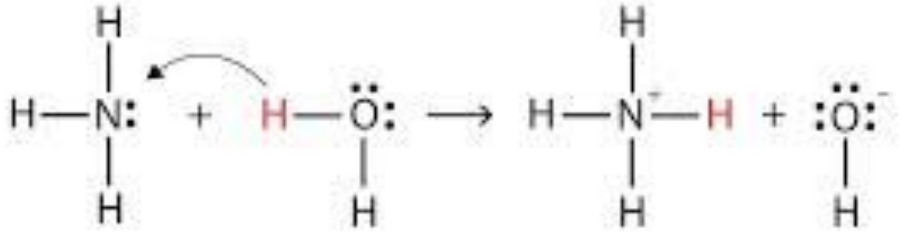
2- Brønsted-Lowry Concept

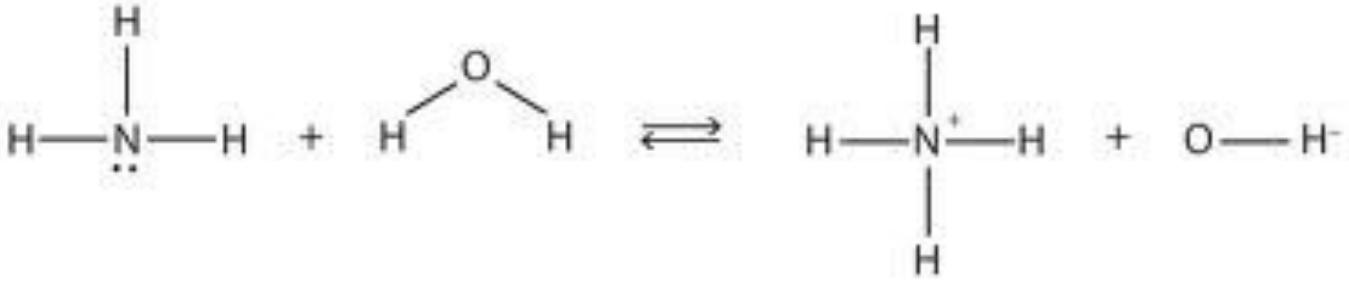
An acid is any molecule or ion that can donate a proton H^+. A base is any molecule or ion can accept a proton.



- proton-transfer reaction

Hydrogen ion acceptor: B-L base

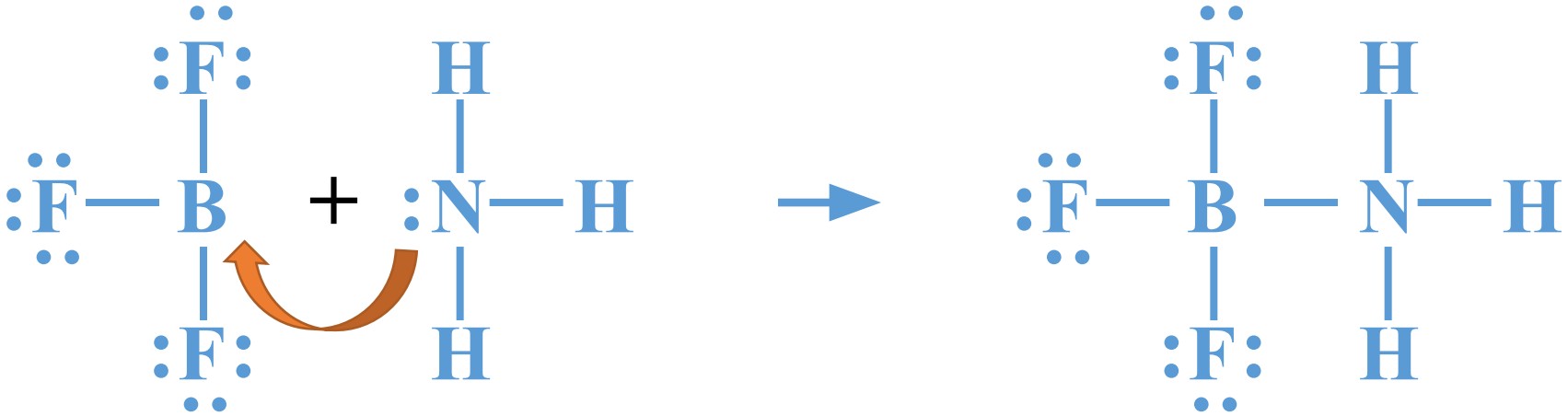
Hydrogen ion donor: B-L acid



BL base BL acid BL acid BL base

3- Lewis Concept

An acid as an electron pair acceptor and a base as an .electron pair donor



Another examples: hydration of $AlCl_3$, BCl_3, OH^-

Strength of Acids and Bases

A strong acid or base ionizes completely in water

Strong Acids	Strong bases
HCl	LiOH
HBr	NaOH
HI	KOH
HNO_3	$Ca(OH)_2$
H_2SO_4	$Sr(OH)_2$
$HClO_4$	$Ba(OH)_2$

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Weak Acids and Bases

A weak acid or base ionizes only to a limited extent in water

Examples: CH_3COOH, NH_3

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Acid or Base Ionization Constant

It is a measure of the strength of acid or base.

The ionization constant has the same equilibrium expression.

$$CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H_3O^+$$

$$K_a = \frac{[CH_3COO^-]\,[H_3O^+]}{[CH_3COOH]}$$

$$NH_3 + H_2O \rightleftharpoons NH_4^+ + HO^-$$

$$K_b = \frac{[NH_4^+]\,[HO^-]}{[NH_3]}$$

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Self-ionization of water

Water acts either as an acid or a base

$$H_2O(l) + H_2O(l) \rightarrow H_3O^+(aq) + OH^-(aq)$$

$$K_w = [H_3O^+][OH^-]$$

Or

$$K_w = [H^+][OH^-]$$

K_w = water dissociation constant

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Self-ionization of water

$$K_w = [H^+][OH^-]$$

$$K_w = 1.0 \times 10^{-14} \qquad \text{at } 25\ ^{o}C$$

$$[H^+] = [OH^-] = \sqrt{1.0 \times 10^{-14}} = 1.0 \times 10^{-7}$$

At 25°C, you observe the following conditions.

an acidic solution, $[H^+] > [OH^-]$
a neutral solution, $[H^+] = [OH^-]$
a basic solution, $[H^+] < [OH^-]$

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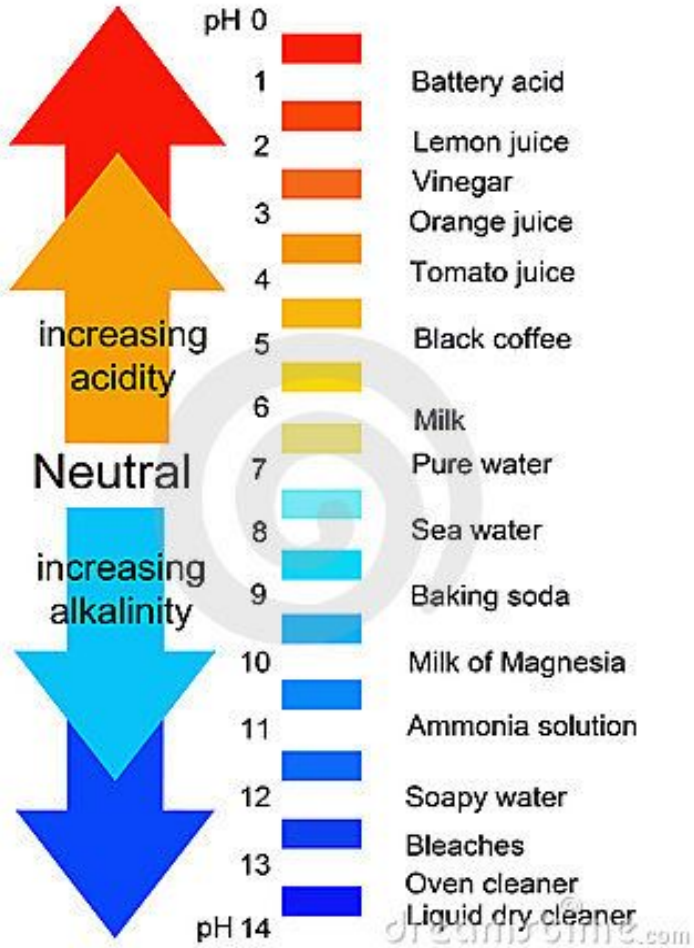
pH of Solutions

The pH of a solution is defined as the negative logarithm of the molar hydrogen-ion concentration

$$pH = -\log[H^+]$$

$$[H^+] = 10^{-pH}$$

$$pH + pOH = 14.00$$



In a **neutral solution**, whose hydrogen-ion concentration is 1.0×10^{-7}, the **pH = 7.00**

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pH of Solutions

At 25°C, you observe the following conditions

In an acidic solution, $[H^+] > 1.0 \times 10^{-7}$ M, pH<7

In a neutral solution, $[H^+] = 1.0 \times 10^{-7}$ M, pH=7

In a basic solution, $[H^+] < 1.0 \times 10^{-7}$ M, pH>7

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Example

For a solution in which the hydrogen-ion concentration is 1.0 x 10-3, the pH is:

$$pH = -\log(1.0 \times 10^{-3}) = 3.00$$

Note that the number of decimal places in the pH equals the number of significant figures in the hydrogen-ion concentration

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Examples

The hydrogen ion concentration of a fruit juice is 3.3×10^{-2} M. What is the pH of the juice? Is it ?acidic or basic

$$pH = -\log(3.3\times10^{-2}) = -(-1.48) = 1.48$$

If a solution has pH of 5.50, calculate its $[OH^-]$

$$14 = pH + pOH$$

$$pOH = 14.00 - 5.50 = 8.50$$

$$pOH = -\log[OH^-]$$

$$\log[OH^-] = -8.50$$

$$[OH^-] = 10^{-8.50} = 3.2 \times 10^{-9}\text{M}$$

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pH of Strong Acids and Bases

Dissociation of a strong base:

$$NaOH \longrightarrow Na^+ + OH^-$$

complete dissociation of a base
and no base in the form of NaOH will be left in solution

$$pOH = -\log[OH^-]$$

$$pH = 14 - pOH = 14 + \log [OH^-]$$

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Example

An ammonia solution has a hydroxide-ion concentration of 1.9 x 10-3 M. What is the pH of the solution?

You first calculate the pOH:

$$\mathbf{pOH = -\log(1.9\times10^{-3}) = 2.72}$$

Then the pH is:

$$\mathbf{pH = 14.00 - 2.72 = 11.28}$$

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pH of Weak Acids and Bases

Dissociation of weak acids (≈Ka < 10^{-4})

Examples: K_a (HF)=7.1 x 10^{-4} , K_a (HCOOH)=1.7 x 10^{-4}

$$\underset{c-x}{HA} \longleftrightarrow \underset{x}{A^-} + \underset{x}{H^+}$$

$$K_a = \frac{[A^-][H^+]}{[HA]} = \frac{x^2}{c-x} = \frac{x^2}{c}$$

c-x = concentration of an acid at equilibrium
x = concentration of products at equilibrium
c = concentration of an acid at the beginning

c >> x
for diluted
weak acids

$$[H^+] = x = (K_a\, c)^{1/2}$$

$$pH = -\log [H^+] = -\log (K_a\, c)^{1/2}$$

$$pK_a = -\log K_a$$

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Question 1

The solution with the lowest pH is

A. 1.0M HF B. 1.0M HCN

C. 1.0M HCOOH D. 1.0M CH_3COOH

Question 2

As the $[H_3O^+]$ in a solution decreases, the $[OH^-]$

A. increases and the pH increases

B. increases and the pH decreases

C. decreases and the pH increases

D. decreases and the pH decreases

Question 3

The value of pK_w at 25°C is

A. 1.0×10^{-14} B. 1.0×10^{-7}

C. 7.00 D. 14.00

Question 4

What is the pOH of 0.1 M NaOH?

A. 1 B. 0.0032

C. 0.40 D. 13.60

Question 5

Which of the following describes the relationship between $[H_3O^+]$ and $[OH^-]$?

A. $[H_3O^+][OH^-] = 14.00$

B. $[H_3O^+] + [OH^-] = 14.00$

C. $[H_3O^+][OH^-] = 1.0 \times 10^{-14}$

D. $[H_3O^+] + [OH^-] = 1.0 \times 10^{-14}$

Question 6

The pH of a solution for which $[OH^-] = 1.0 \times 10^{-6}$ is

A. 1.00 B. 8.00

C. 6.00 D. –6.00

Question 7

The ionization of water at room temperature is represented by

A. $H_2O = 2H^+ + O^{2-}$

B. $2H_2O = 2H_2 + O_2$

C. $2H_2O = H_2 + 2OH^-$

D. $2H_2O = H_3O^+ + OH^-$

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Question 8

According to the Bronsted-Lowry theory, a base is a(n)

A. proton donorvv
B. proton acceptor
C. electron donor
D. electron acceptor

Question 9

the pH of 1.0 M acetic acid (Ka is 1.86 x10^{-5} at 20 °C).

E. 1.37
F. 2.37
G. 3.73
H. 4.73

Question 10

Addition of HCl to water causes

A. both $[H_3O^+]$ and $[OH^-]$ to increase
B. both $[H_3O^+]$ and $[OH^-]$ to decrease
C. $[H_3O^+]$ to increase and $[OH^-]$ to decrease
D. $[H_3O^+]$ to decrease and $[OH^-]$ to increase

Question 11

Which of the following statements concerning Arrhenius acids and Arrhenius bases is correct?

A. In the pure state, Arrhenius acids are covalent compounds.
B. In the pure state, Arrhenius bases are ionic compounds
C. Dissociation is the process by which Arrhenius acids produce H^+ ions in solution
D. Arrhenius bases are also called hydroxide bases

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Thermochemistry

Chapter
8

COURSE NAME: CHEMISTRY 101
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Energy

Energy is the capacity to do work.

- ***Thermal energy*** is the energy associated with the random motion of atoms and molecules
- ***Chemical energy*** is the energy stored within the bonds of chemical substances
- ***Nuclear energy*** is the energy stored within the collection of neutrons and protons in the atom
- ***Potential energy*** is the energy available by virtue of an object's position

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Kinds of Systems

Open system

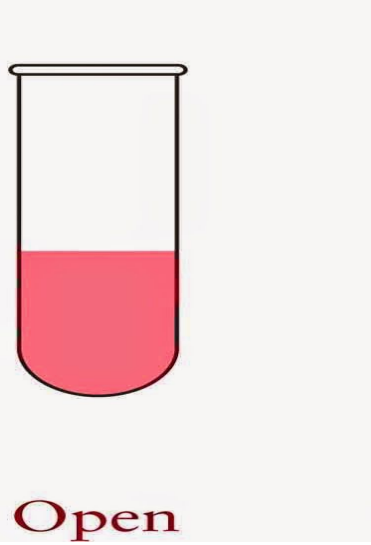
can exchange mass and energy

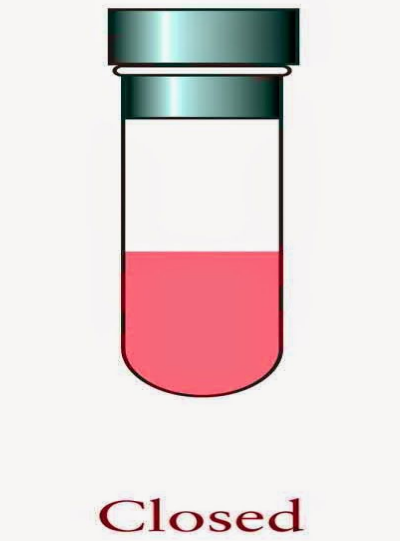
Closed system

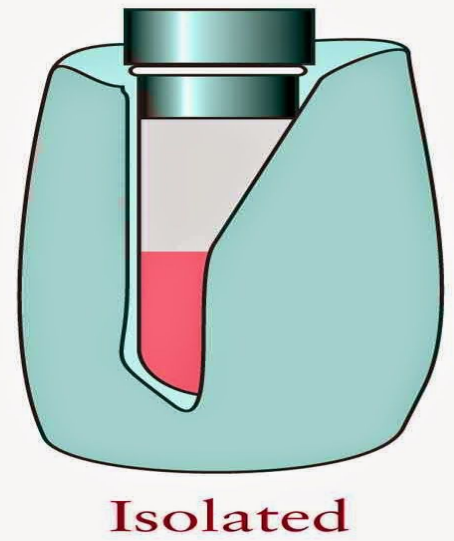
allows the transfer of energy (heat) but not mass

Isolated system

doesn't allow transfer of either mass or energy







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Examples

Thermodynamics

Thermodynamics is the scientific study of the interconversion of heat and other kinds of energy

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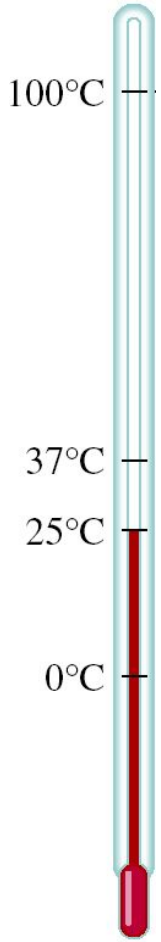
Heat (q)

Heat is the transfer of thermal energy between two bodies that are at different temperatures.

Temperature is a measure of the thermal energy

Temperature ≠ Thermal Energy



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First Law of Thermodynamics

First Law: Energy of the Universe is Constant

$$E = q + w$$

q = heat. Transferred between two bodies

w = work. Force acting over a distance (F x d)

$$w = F \times d$$

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Thermodynamic State Functions

- Thermodynamic State Functions: Thermodynamic properties that are dependent on the state of the system only regardless of the pathway. Examples: (Energy, pressure, volume, temperature)

$$\Delta E = E_{final} - E_{initial}$$

$$\Delta P = P_{final} - P_{initial}$$

$$\Delta V = V_{final} - V_{initial}$$

$$\Delta T = T_{final} - T_{initial}$$

- Other variables will be dependent on pathway (Examples: q and w). These are Path Functions. The pathway from one state to the other must be defined.

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Thermochemistry

Thermochemistry is the study of **heat change** in chemical reactions.

Exothermic process is any process that gives off heat – transfers thermal energy from the system to the surroundings.

$$2H_2\,(g) + O_2\,(g) \longrightarrow 2H_2O\,(l) + \text{energy}$$

$$H_2O\,(g) \longrightarrow H_2O\,(l) + \text{energy}$$

Endothermic process is any process in which heat has to be supplied to the system from the surroundings.

$$\text{energy} + 2HgO\,(s) \longrightarrow 2Hg\,(l) + O_2\,(g)$$

$$\text{energy} + H_2O\,(s) \longrightarrow H_2O\,(l)$$

Enthalpy of Chemical Reactions

Definition of Enthalpy

- Thermodynamic Definition of Enthalpy (H):

$$H = E + PV$$

E = energy of the system
P = pressure of the system
V = volume of the system

Changes in Enthalpy (ΔH)

- Consider the following expression for a chemical process:

$$\Delta H = H_{products} - H_{reactants}$$

If $\Delta H > 0$, then $q_p > 0$. (+) The reaction is endothermic

If $\Delta H < 0$, then $q_p < 0$. (-) The reaction is exothermic

$$\Delta H = q_p$$

q_p : heat at constant pressure

Calorimetry: the measurement of heat change

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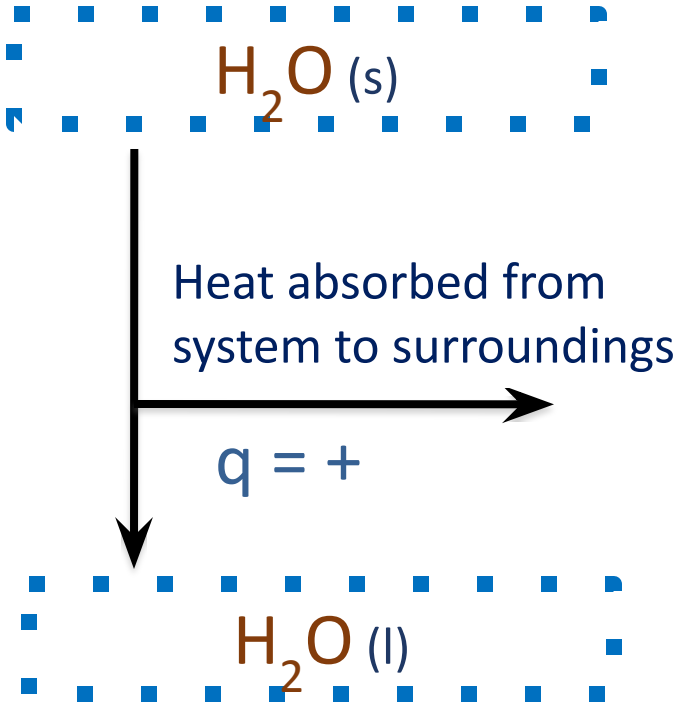
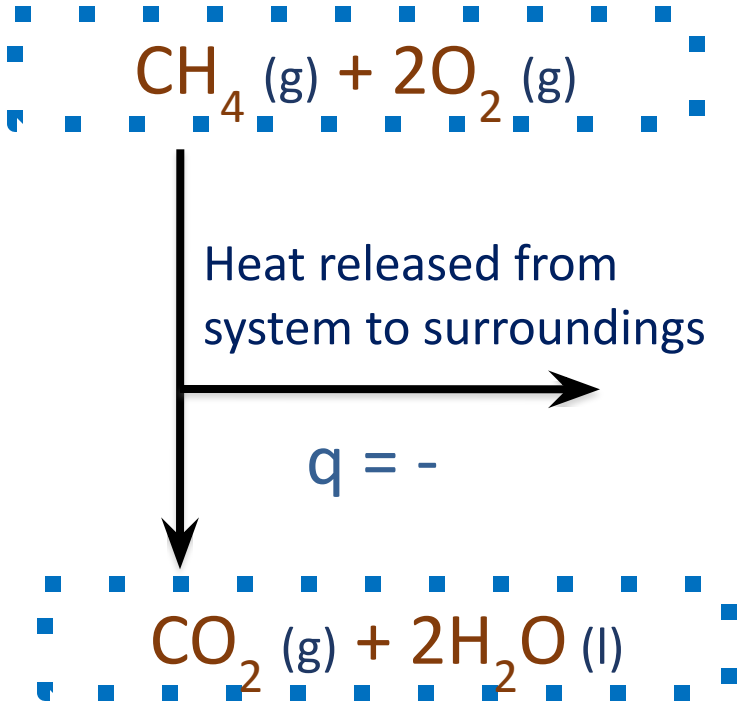
Kinds of Processes
(chemical reactions or physical changes)

Endothermic processes



Exothermic processes



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Standard Enthalpy (Heat) of reaction (ΔH^o_{rxn})

Enthalpy change at standard conditions (25 ^oC, 1 atm)

$$N_2\,(g) + 3H_2\,(g) \longrightarrow 2NH_3\,(g) \quad \Delta H^o = -92.38\ kJ$$

Thermochemical reaction

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Standard Heat of formation (ΔH_f^o)

The heat change that results when 1 mol of the compound is formed from standard state of its elements

The standard enthalpy of formation of any element in its most stable form is zero.

ΔH^0 (C, diamond) = 1.90 kJ/mol

What is ΔH_f^o of O_2 (g), Hg(l), C(graphite)?

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Thermochemical Equations

$$CH_4\,(g) + 2O_2\,(g) \longrightarrow CO_2\,(g) + 2H_2O\,(l) \quad \Delta H = -890.4\ kJ/mol$$

- It shows the physical states of all products and reactants
- Balanced
- It shows Heat of reaction kJ

$$H_2O\,(s) \longrightarrow H_2O\,(l) \qquad \Delta H = 6.01\ kJ/mol$$

- If you reverse a reaction, the sign of ΔH changes

$$H_2O\,(l) \longrightarrow H_2O\,(s) \qquad \Delta H = -6.01\ kJ/mol$$

- If you multiply both sides of the equation by a factor *n*, then ΔH must change by the same factor *n*.

$$2H_2O\,(s) \longrightarrow 2H_2O\,(l) \qquad \Delta H = 2 \times 6.01 = 12.0\ kJ$$

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Question 1

An exothermic reaction causes the surroundings to:

A. become basic B. decrease in temperature
C. condense D. increase in temperature

Question 2

Standard enthalpy of reactions can be calculated from standard enthalpies of formation of reactants.

A. True
B. False

Question 3

Given: SO2(g) + ½O2(g) ----> SO3(g) ΔH^{o}_{rxn} = -99 kJ, what is the enthalpy change for the following reaction? 2 SO3(g) ----> O2(g) + 2 SO2(g)

C. 99 kJ B. -99 kJ
C. 49.5 kJ D. 198 kJ

Question 4

Energy is the ability to do work and can be:

A. converted to one form to another
B. can be created and destroyed
C. used within a system without consequences
D. none of the above

Question 5

To which one of the following reactions, occurring at 25°C, does the symbol ΔH^{o}_{f} [H_2SO_4(l)] refer?

E. H2(g) + S(s) + 2 O2(g) ----> H2SO4(l)
F. H2SO4(l) ----> H2(g) + S(s) + 2 O2(g)
G. H2(g) + S(g) + 2 O2(g) ----> H2SO4(l)
H. H2SO4(l) ----> 2 H(g) + S(s) + 4 O(g)
I. 2 H(g) + S(g) + 4 O(g) ----> H2SO4(l)

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Elements that exist as gases at 25^0C and 1 atmosphere

1A												3A	4A	5A	6A	7A	8A
H	2A																He
Li	Be											B	C	N	O	F	Ne
Na	Mg	3B	4B	5B	6B	7B		8B			1B	2B	Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr	
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe	
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn	
Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg								

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TABLE 5.1 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)*

*The boiling point of HCN is 26°C, but it is close enough to qualify as a gas at ordinary atmospheric conditions.

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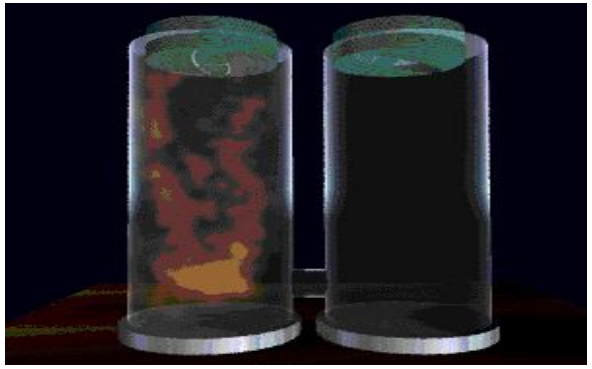
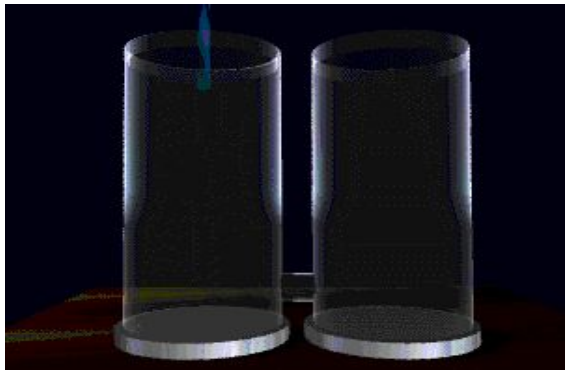
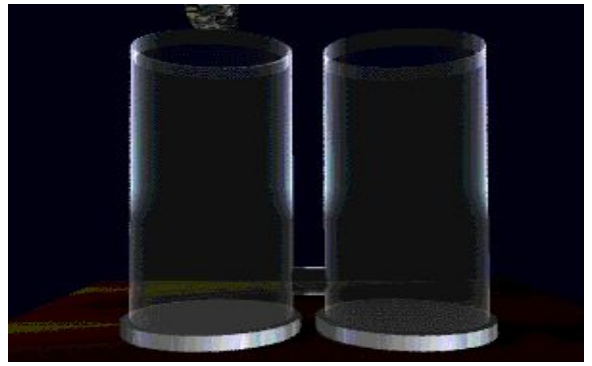
Physical Characteristics of Gases

- Gases assume the volume and shape of their containers.
- Gases are the most compressible state of matter.
- Gases will mix evenly and completely when confined to the same container.
- Gases have much lower densities than liquids and solids.







$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

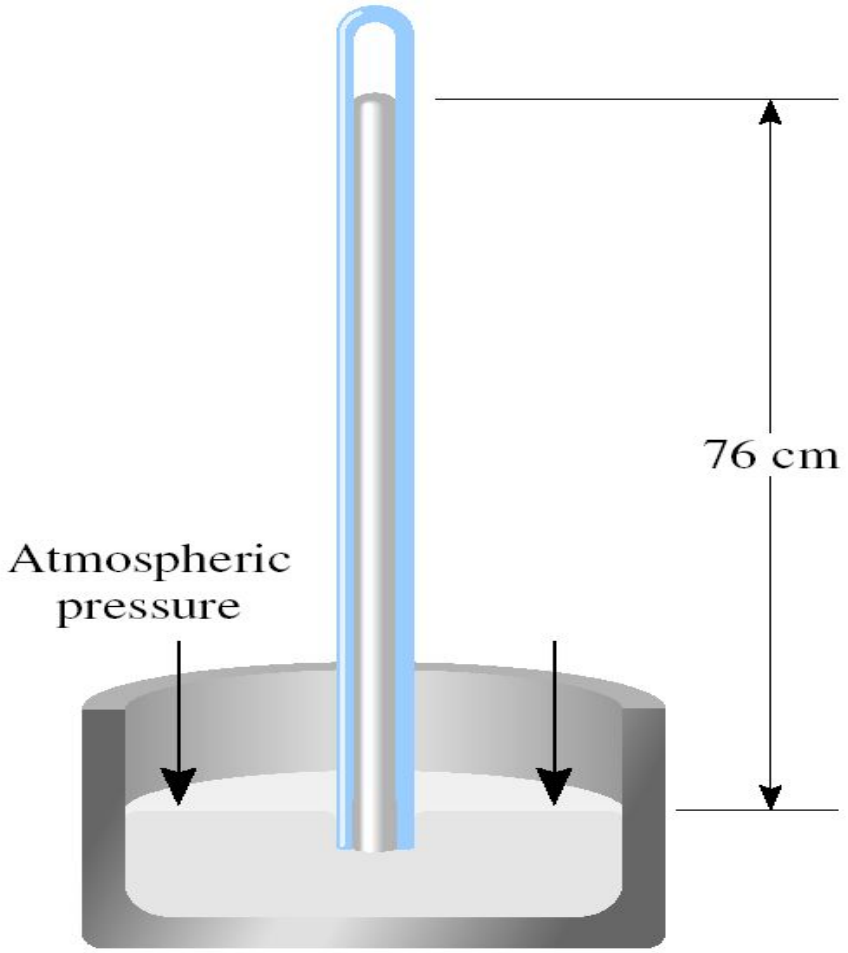
(force = mass x acceleration)

Units of Pressure

1 pascal (Pa) = 1 N/m^2

1 atm = 760 mmHg = 760 torr

1 atm = 101,325 Pa



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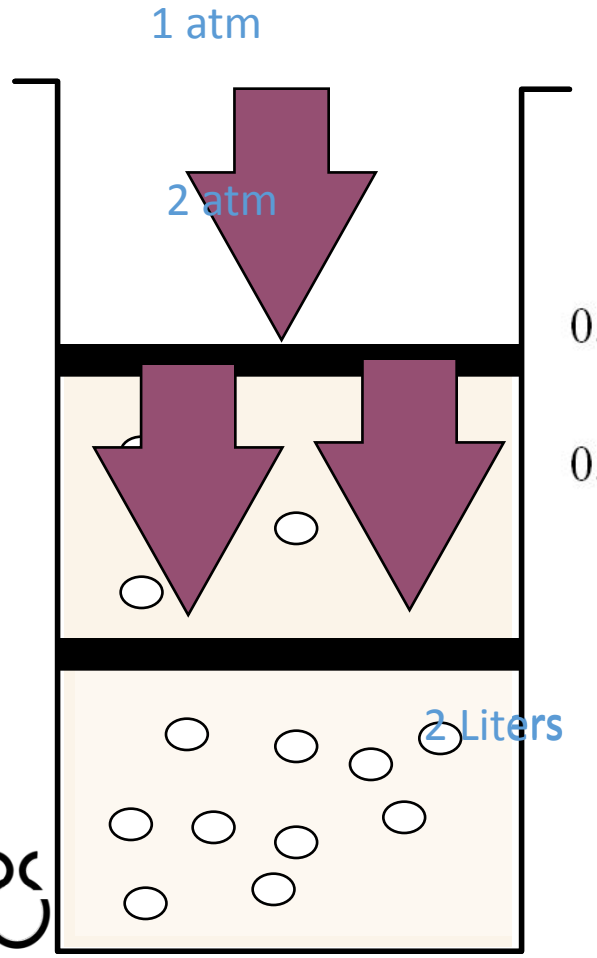
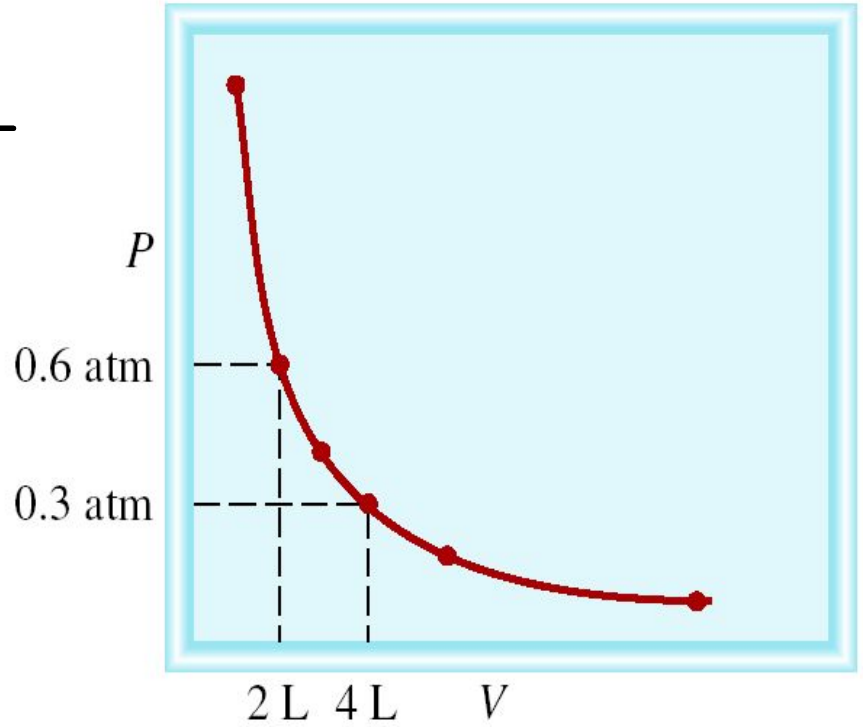
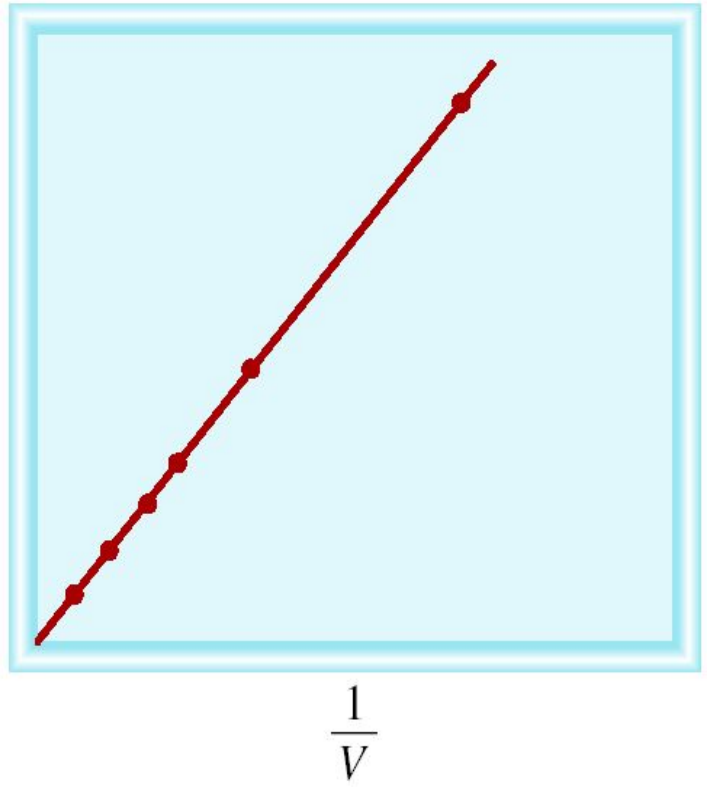
- **Boyle's law:** The volume of a given amount of gas held at constant temperature varies inversely with the applied pressure.







$P \alpha 1/V$

$P \times V = \text{constant}$

$P_1 \times V_1 = P_2 \times V_2$

T = Constant

n = Constant

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A sample of chlorine gas occupies a volume of 946 mL at a pressure of 726 mmHg. What is the pressure of the gas (in mmHg) if the volume is reduced at constant temperature to 154 mL?

$$P \times V = constant$$

$$P_1 \times V_1 = P_2 \times V_2$$

$P_1 = 726$ mmHg $\qquad P_2 = ?$

$V_1 = 946$ mL $\qquad V_2 = 154$ mL

$$P_2 = \frac{P_1 \times V_1}{V_2} = \frac{726 \text{ mmHg} \times 946 \cancel{\text{mL}}}{154 \cancel{\text{mL}}} = 4460 \text{ mmHg}$$

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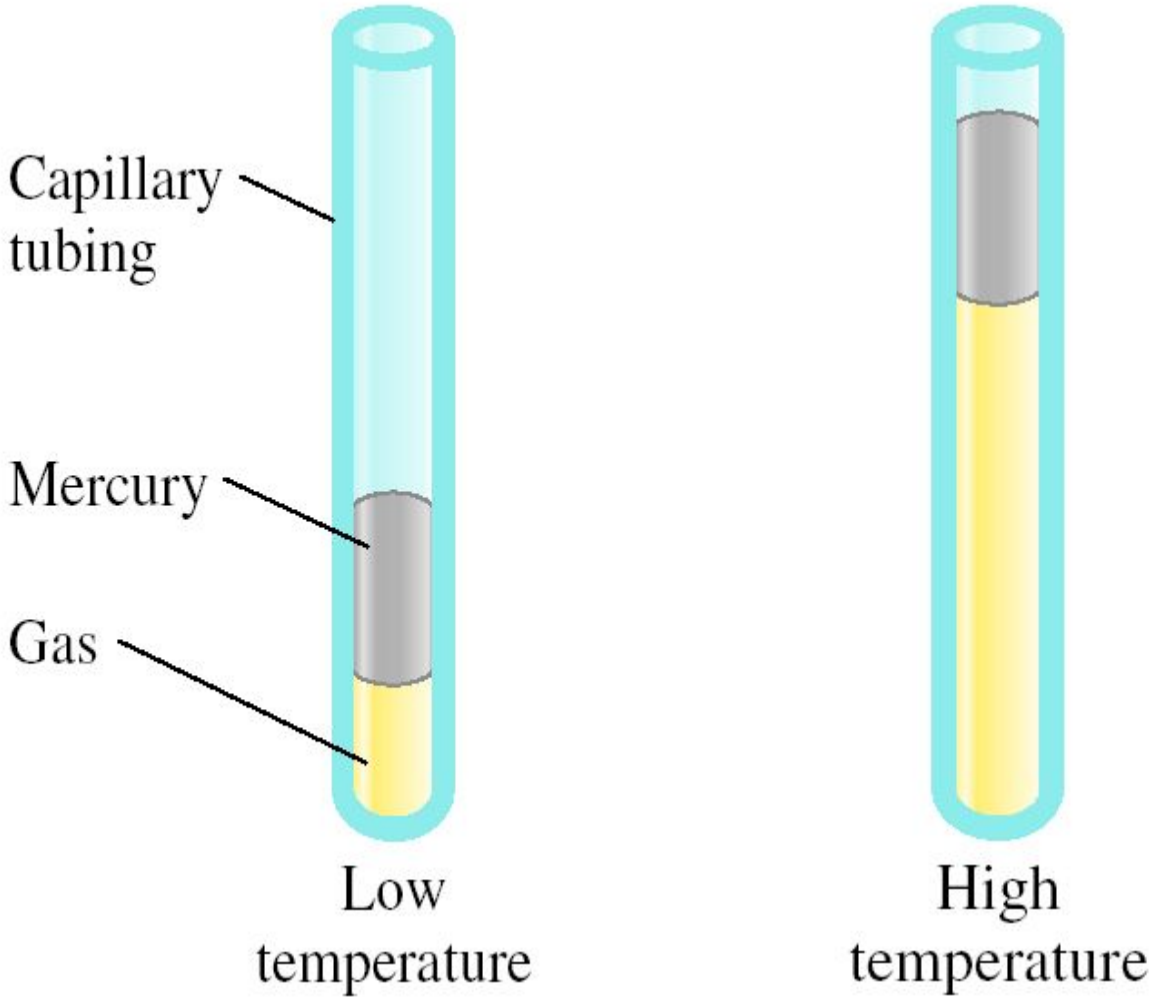
Variation in Gas Volume with Temperature at Constant Pressure



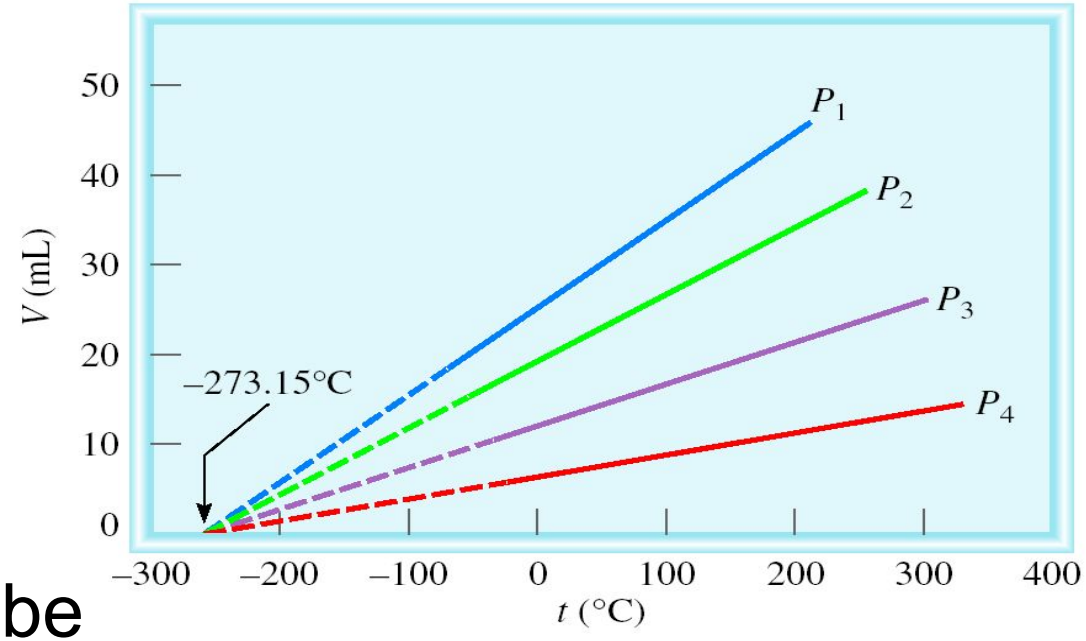
As T increases V increases

Charles's Law: The volume of a given amount of gas held at constant pressure is directly proportional to the Kelvin temperature

$$V \propto T$$

$$V = \text{constant} \times T$$

$$V_1/T_1 = V_2/T_2$$



Temperature **must** be in Kelvin

$$T\,(\text{K}) = t\,(^0\text{C}) + 273.15$$

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A sample of carbon monoxide gas occupies 3.20 L at 125 ^{0}C. At what temperature will the gas occupy a volume of 1.54 L if the pressure remains constant?

$$V_1 / T_1 = V_2 / T_2$$

$V_1 = 3.20$ L $\qquad V_2 = 1.54$ L

$T_1 = 398.15$ K $\qquad T_2 = ?$

$T_1 = 125\ (^0\text{C}) + 273.15\ (\text{K}) = 398.15$ K

$$T_2 = \frac{V_2 \times T_1}{V_1} = \frac{1.54\ \text{L} \times 398.15\ \text{K}}{3.20\ \text{L}} = 192\ \text{K}$$

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- **Gay-Lussac's Law:** The pressure of a given amount of gas held at constant volume is directly proportional to the Kelvin temperature.

$$\frac{P}{T} = \text{a constant} \quad \text{or} \quad \frac{P_1}{T_1} = \frac{P_2}{T_2}$$

Argon is an inert gas used in lightbulbs to retard the vaporization of the filament. A certain lightbulb containing argon at 1.20 atm and 18 ^{0}C is heated to 85 ^{0}C at constant volume. What is the final pressure of argon in the lightbulb (in atm)?

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

$P_1 = 1.20$ atm $\quad P_2 = ?$

$T_1 = 291$ K $\quad T_2 = 358$ K

$$P_2 = P_1 \times \frac{T_2}{T_1} = 1.20 \text{ atm} \times \frac{358 \text{ K}}{291 \text{ K}} = 1.48 \text{ atm}$$

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Summary

LAW	RELAT-IONS HIP	LAW	CON-STANT
Boyle's	$P\uparrow V\downarrow$	$P_1V_1 = P_2V_2$	T, n
Charles'	$V\uparrow T\uparrow$	$V_1/T_1 = V_2/T_2$	P, n
Gay-Lussac's	$P\uparrow T\uparrow$	$P_1/T_1 = P_2/T_2$	V, n

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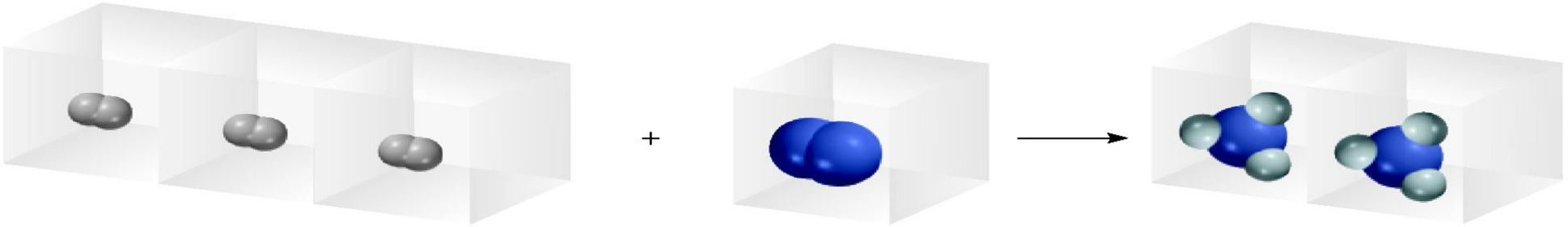
Avogadro's Law

$V \alpha$ number of moles (n)

V = constant x n

Constant temperature
Constant pressure

$$V_1 / n_1 = V_2 / n_2$$



$3H_2(g)$	+	$N_2(g)$	⟶	$2NH_3(g)$
3 molecules	+	1 molecule	⟶	2 molecules
3 moles	+	1 mole	⟶	2 moles
3 volumes	+	1 volume	⟶	2 volumes

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Ammonia burns in oxygen to form nitric oxide (NO) and water vapor. How many volumes of NO are obtained from one volume of ammonia at the same temperature and pressure?

$$4NH_3 + 5O_2 \longrightarrow 4NO + 6H_2O$$

$$1 \text{ mole } NH_3 \longrightarrow 1 \text{ mole NO}$$

At constant *T* and *P*

$$1 \text{ volume } NH_3 \longrightarrow 1 \text{ volume NO}$$

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Ideal Gas Equation

Boyle's law: $P \alpha \frac{1}{V}$ (at constant n and T)

Charles' law: $V \alpha T$ (at constant n and P)

Avogadro's law: $V \alpha n$ (at constant P and T)

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

$$V = \text{constant} \times \frac{nT}{P} = \frac{R\,nT}{P}$$

R is the **gas constant**

$$PV = nRT$$

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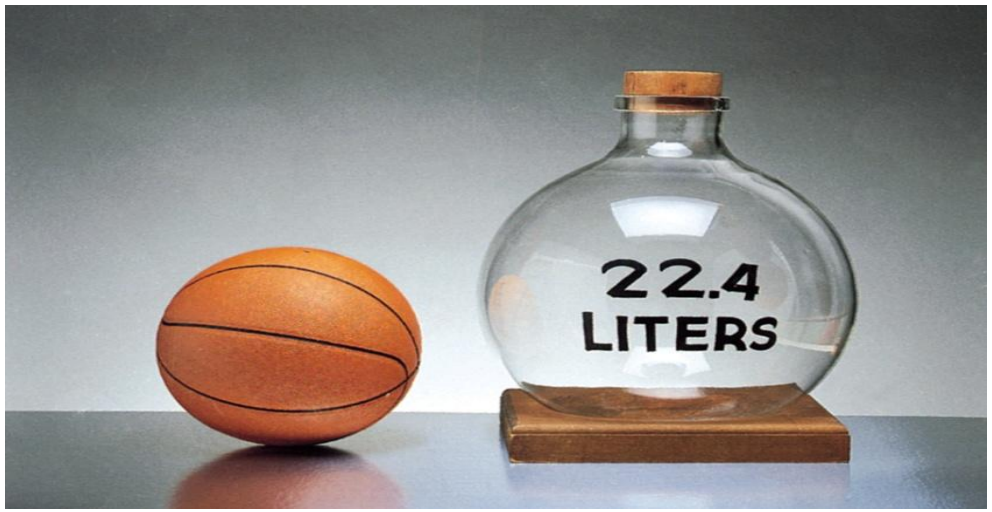
The conditions 0 ^{0}C and 1 atm are called **standard temperature and pressure (STP).**



Experiments show that at STP, 1 mole of an ideal gas occupies 22.414 L.

$$PV = nRT$$

$$R = \frac{PV}{nT} = \frac{(1\ \text{atm})(22.414\text{L})}{(1\ \text{mol})(273.15\ \text{K})}$$

$$R = 0.082057\ \text{L} \cdot \text{atm} / (\text{mol} \cdot \text{K})$$

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What is the volume (in liters) occupied by 49.8 g of HCl at STP?

$T = 0\ ^{0}C = 273.15\ K$

$P = 1\ atm$

$PV = nRT$

$V = \dfrac{nRT}{P}$

$n = 49.8\ g \times \dfrac{1\ mol\ HCl}{36.45\ g\ HCl} = 1.37\ mol$

$$V = \frac{1.37\ \cancel{mol} \times 0.0821 \dfrac{L \cdot \cancel{atm}}{\cancel{mol} \cdot \cancel{K}} \times 273.15\ \cancel{K}}{1\ \cancel{atm}}$$

$V = 30.7\ L$

Questions

1.Which of the following is not a characteristic of substances in the gas phase?

A)Substances in the gas phase have much lower densities than the same substances would have in the liquid or solid phase.

B)A mixture of substances in the gas phase will form a homogeneous solution, whereas the same mixture might not form a homogeneous solution in the liquid phase.

C)Substances in the gas phase retain their shapes easily.

D)Substances in the gas phase are compressible.

2. A sample of gas occupies 2.78 x 10^3 mL at 25°C and 760 mm Hg. What volume will the gas sample occupy at the same temperature and 475 mm Hg?

A) 0.130 L

B) 1.04 L

C) 1.74 L

D) 4.45 L

E) None of the above

3.A steel tank contains carbon dioxide at a pressure of 13.0 atm when the temperature is 34°C. What will be the internal gas pressure when the tank and its contents are heated to 100°C.

A) 38.2 atm

B) 9.40 atm

C) 10.7 atm

D) 15.8 atm

E) None of the above.

4.Which of the following correctly identifies Boyle's law?

A) $PV=k_1$

B) $V=k_2T$

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Questions

5. A gas evolved during the fermentation of alcohol had a volume of 19.4 L at 17°C and 746 mm Hg. How many moles of gas were collected?

A) 1.25 mol

B) 0.800 mol

C) 10.5 mol

D) 13.6 mol

E) 608 mol

6. How many grams of carbon dioxide are contained in 550 mL of this gas at STP?

A) 0.0245 g

B) 0.0280 g

C) 1080 g

D) 0.560 g

E) 1.1 g

7. A 1.325 g sample of an unknown vapor occupies 368 mL at 114°C and 946 mm Hg. The empirical formula of the compound is NO_2. What is the molecular formula of the compound?

A) NO_2

B) N_4O_8

C) N_3O_6

D) N_2O_4

E) N_5O_{10}.

8. A sample of $CO_2(g)$ has a volume of 2L at pressure P and temperature T. If the pressure becomes triple the original value, at the same absolute temperature, the volume of CO_2 will be

A) L

B) **2/3** L

C) 6L

D) 2L

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كلية العلوم التطبيقية
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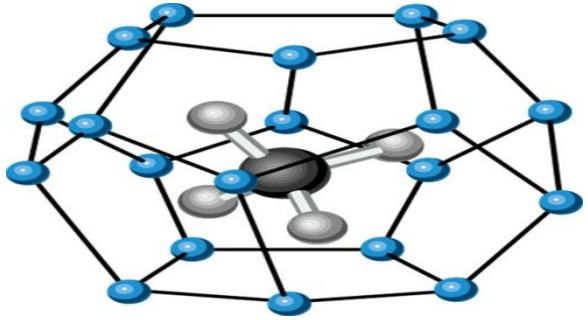

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ORGANIC CHEMISTRY

Chapter

10

COURSE NAME: CHEMISTRY 101
COURSE CODE: 402101-4

Organic Chemistry

- The study of the compounds of carbon
- Over 10 million compounds have been identified
  - about 1000 new ones are identified each day!
- C is a small atom
  - it forms single, double, and triple bonds
  - it is intermediate in electronegativity (2.5)
  - it forms strong bonds with C, H, O, N, and some metals

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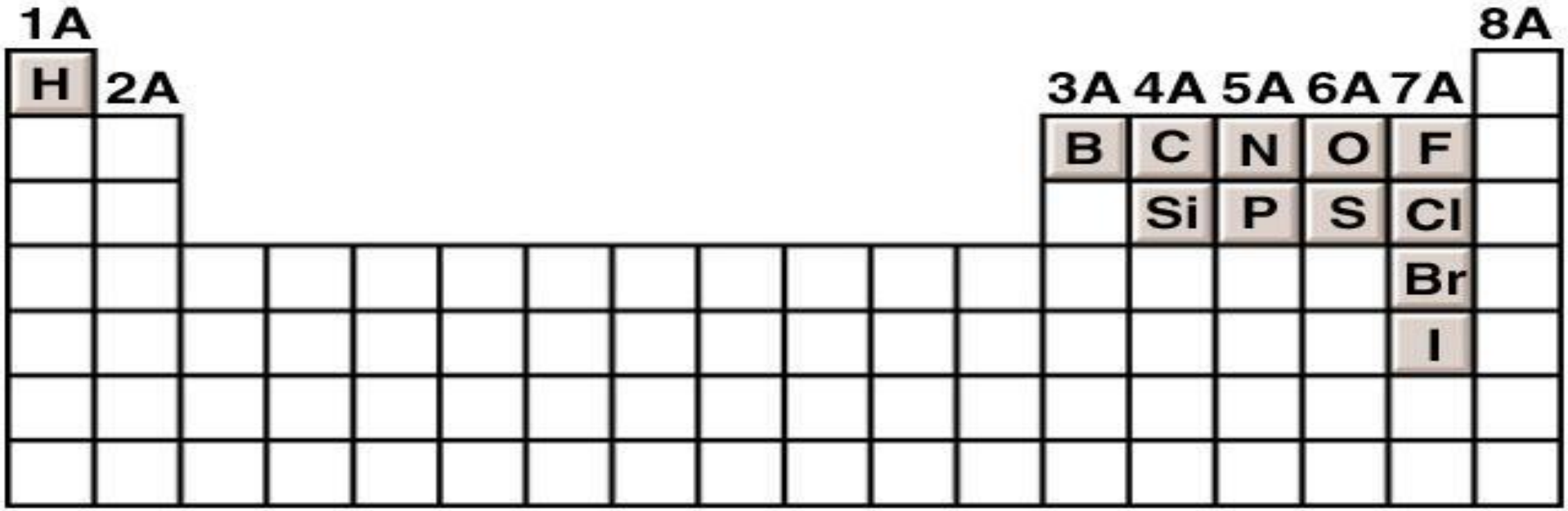
Common Elements in Organic Compounds



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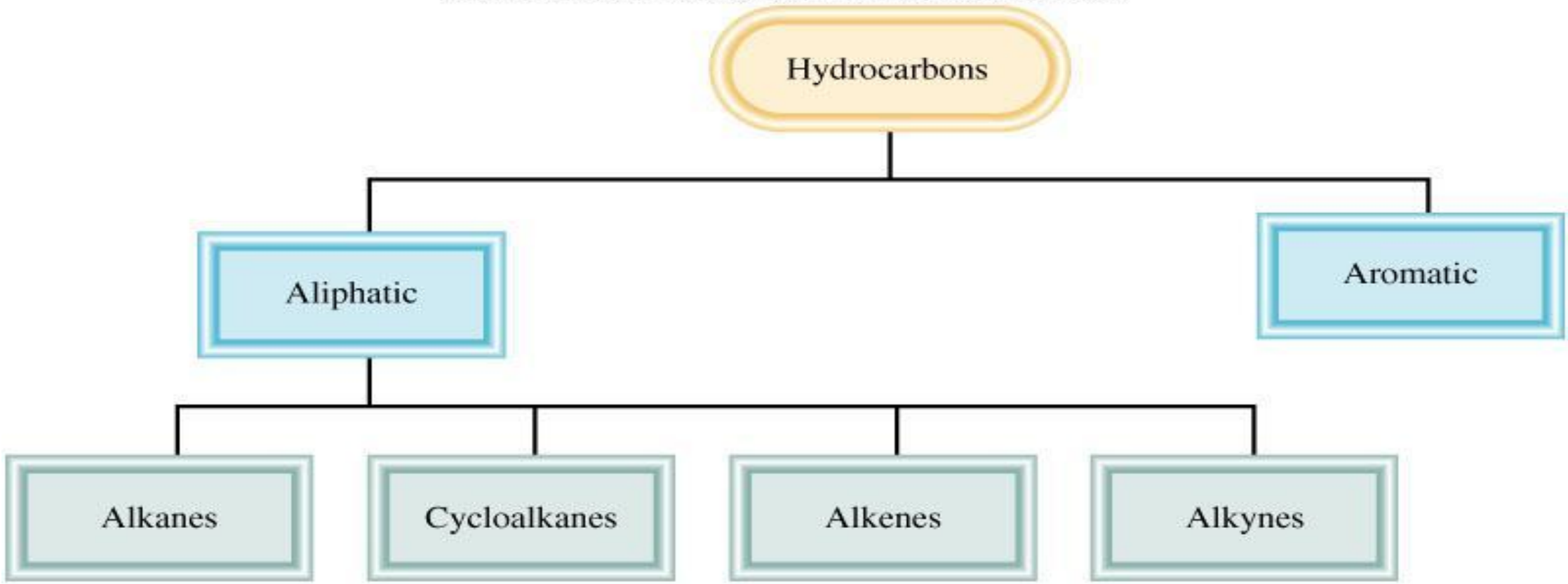
Classification of Hydrocarbons



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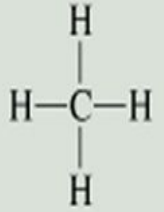
Alkanes

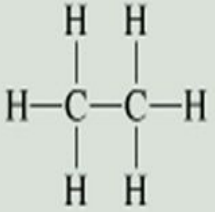
Alkanes have the general formula C_nH_{2n+2} where n = 1,2,3,…

1. only single covalent bonds
2. **saturated hydrocarbons** because they contain the **maximum** number of hydrogen atoms that can bond with the number of carbon atoms in the molecule

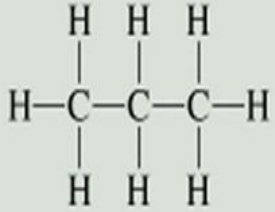
# of carbons	boiling point range	Use
1-4	<20 °C	fuel (gasses such as methane, propane, butane)
5-6	30-60	solvents (petroleum ether)
6-7	60-90	solvents (ligroin)
6-12	85-200	fuel (gasoline)
12-15	200-300	fuel (kerosene)
15-18	300-400	fuel (heating oil)
16-24	>400	lubricating oil, asphalt



Methane



Ethane



Propane

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Alkane Nomenclature

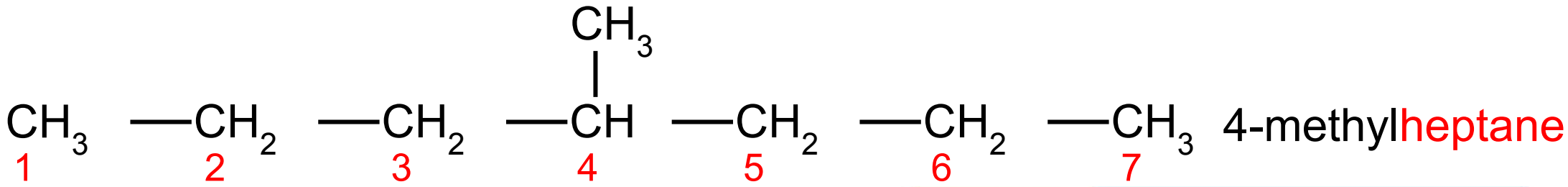
The First 10 Straight-Chain Alkanes

Name of Hydrocarbon	Molecular Formula	Number of Carbon Atoms	Melting Point (°C)	Boiling Point (°C)
Methane	CH_4	1	−182.5	−161.6
Ethane	$CH_3—CH_3$	2	−183.3	−88.6
Propane	$CH_3—CH_2—CH_3$	3	−189.7	−42.1
Butane	$CH_3—(CH_2)_2—CH_3$	4	−138.3	−0.5
Pentane	$CH_3—(CH_2)_3—CH_3$	5	−129.8	36.1
Hexane	$CH_3—(CH_2)_4—CH_3$	6	−95.3	68.7
Heptane	$CH_3—(CH_2)_5—CH_3$	7	−90.6	98.4
Octane	$CH_3—(CH_2)_6—CH_3$	8	−56.8	125.7
Nonane	$CH_3—(CH_2)_7—CH_3$	9	−53.5	150.8
Decane	$CH_3—(CH_2)_8—CH_3$	10	−29.7	174.0

Each member C_3 - C_{10} differs by one CH_2 unit. This is called a homologous series.
Methane to butane are gases at normal pressures.
Pentane to decane are liquids at normal pressures.

Alkane Nomenclature

1. The parent name of the hydrocarbon is that given to the longest continuous chain of carbon atoms in the molecule.



4-methylheptane

2. Alkyl substituents: An alkane less one hydrogen atom is an alkyl group.

drop the -ane and add -yl.

$-CH_3$: methyl

$-C_2H_5$: ethyl

Common Alkyl Groups

Name	Formula
Methyl	$—CH_3$
Ethyl	$—CH_2—CH_3$
n-Propyl	$—CH_2—CH_2—CH_3$
n-Butyl	$—CH_2—CH_2—CH_2—CH_3$
Isopropyl	$—CH(CH_3)_2$
t-Butyl*	$—C(CH_3)_3$

*The letter *t* stands for tertiary.

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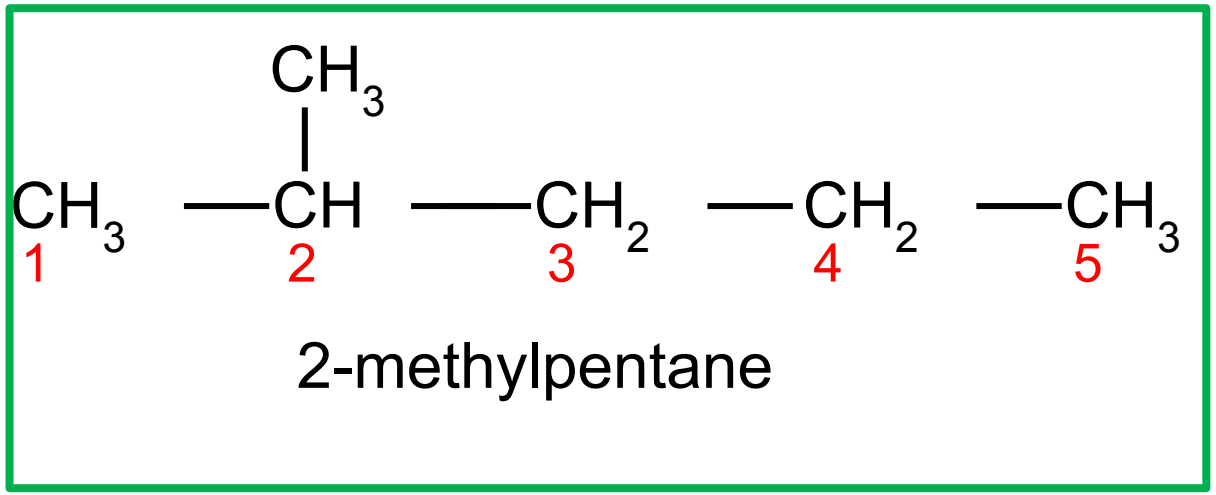
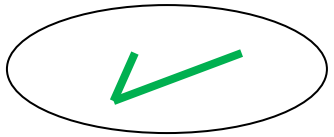
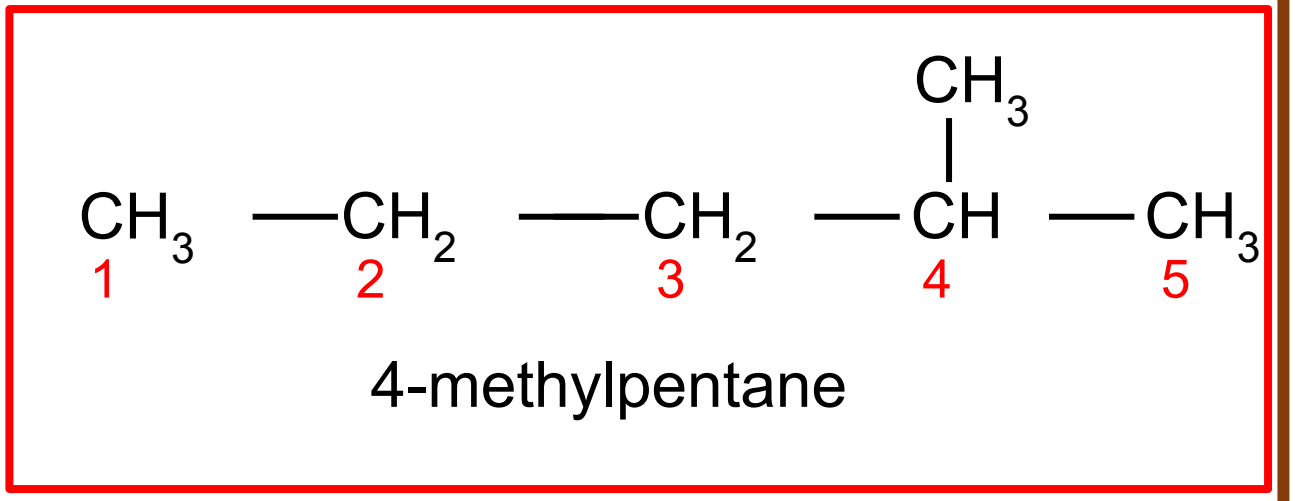
Alkane Nomenclature

3. When one or more hydrogen atoms are replaced by other groups, the name of the compound must indicate the locations of carbon atoms where replacements are made. Number in the direction that gives the smaller numbers for the locations of the branches.

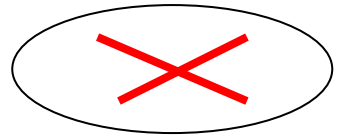


2-methylpentane



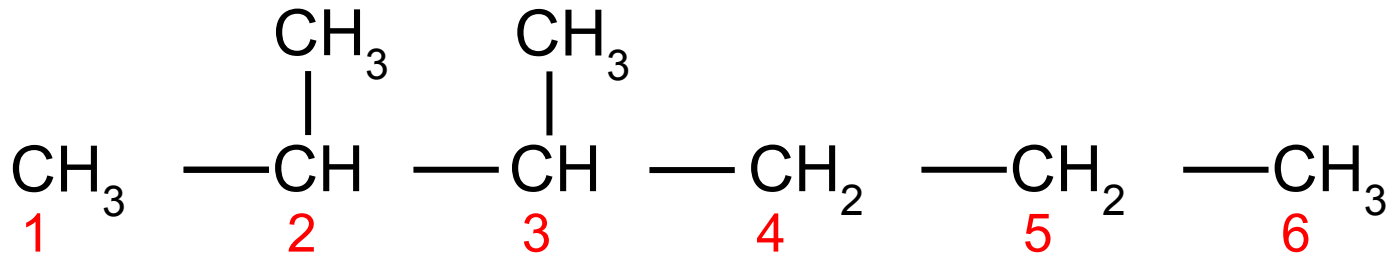


4-methylpentane

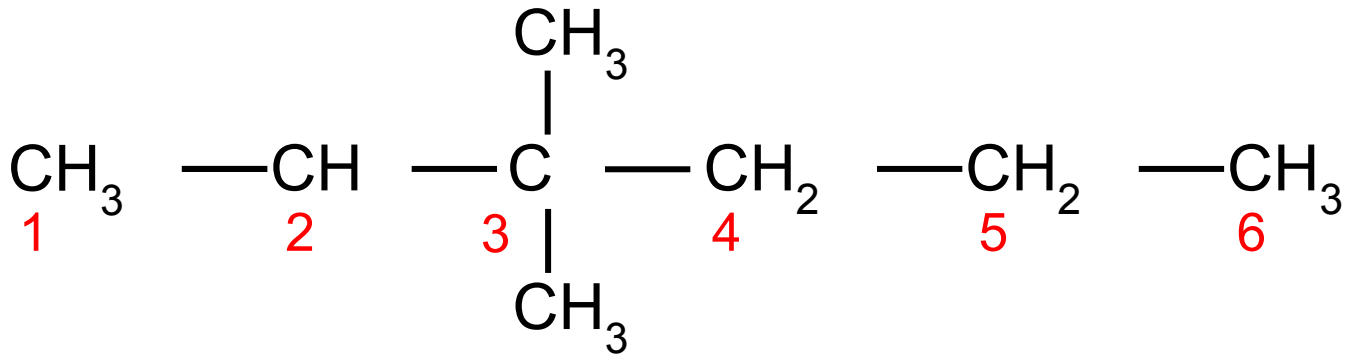


Alkane Nomenclature

4. Use prefixes *di-, tri-, tetra-*, when there is more than one alkyl branch of the same kind.



2,3-dimethylhexane



3,3-dimethylhexane

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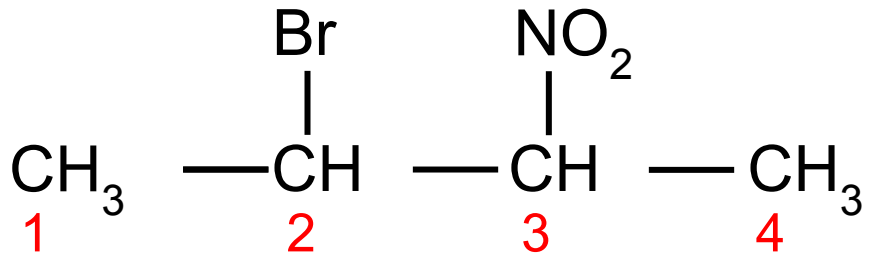
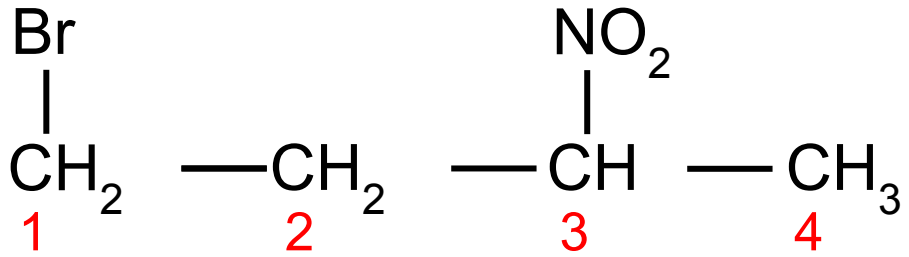
Alkane Nomenclature

5. Use previous rules for other types of substituents.



2-bromo-3-nitrobutane



1-bromo-3-nitrobutane

TABLE

Names of Common Substituent Groups

Functional Group	Name
—NH_2	Amino
—F	Fluoro
—Cl	Chloro
—Br	Bromo
—I	Iodo
—NO_2	Nitro
—CH=CH_2	Vinyl

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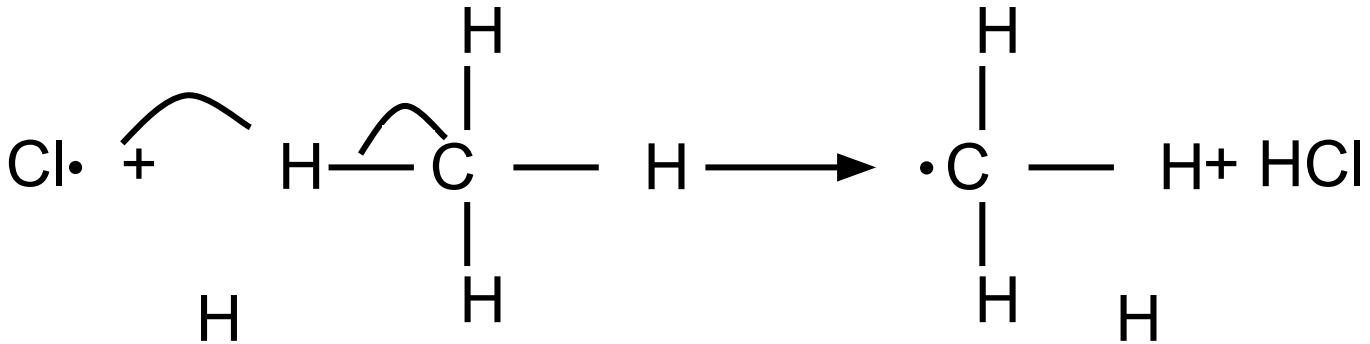
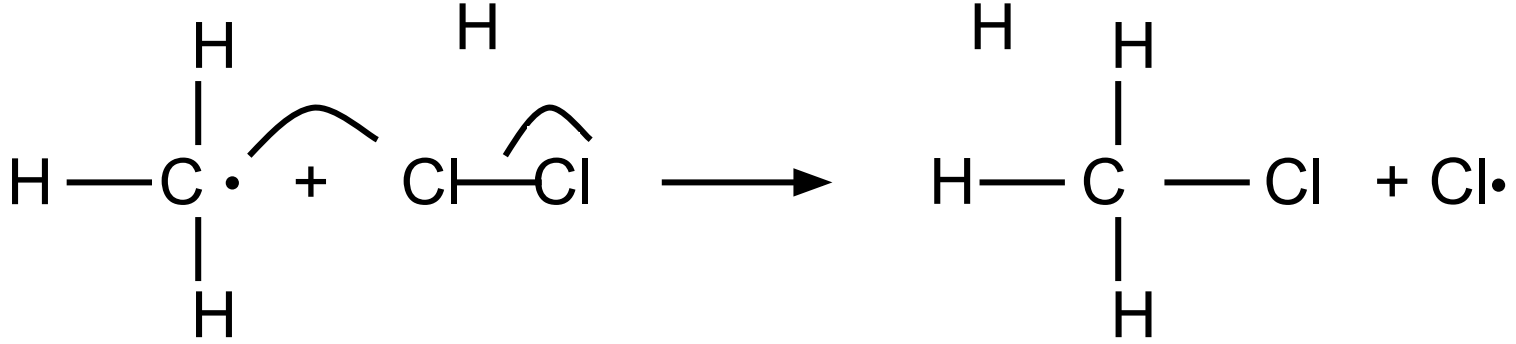
Alkane Reactions

Combustion $CH_4\ (g) + 2O_2\ (g) \longrightarrow CO_2\ (g) + 2H_2O\ (l)\quad \Delta H^0 = -890.4\ kJ$

Halogenation $CH_4\ (g) + Cl_2\ (g) \xrightarrow{light} CH_3Cl\ (g) + HCl\ (g)$

$Cl_2 + energy \longrightarrow Cl\bullet + Cl\bullet$





Questions

1- Organic compounds must contain

A) Oxygen

B) Nitrogen

C) Hydrogen

D) Carbon

2- Which formula represents a saturated hydrocarbon? A) C2H2

B) C3H8

C) C3H6

D) C2H4

4- How many carbon atoms are present per molecule in the compound 3-methyl-4-ethyloctane? How many of those are present on the side chains (branches) only?

A) 11 total; 3 on branches

B) 15 total; 7 on branches

C) 12 total; 3 on branches

D) 15 total; 2 on branches

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5- How many hydrogen atoms would be part of one molecule of pentane?

A) 5

B) 8

C) 10

D) 12

6- C2H4 + Br2 = ? What reaction occurs when the above chemicals react?

A) substitution

B) Addition

C) Elimination

D) hydrolysis

7- The general formula for the alkane series is :

A) CnHn

B) CnH2n

C) CnH2n+2

D) CnH2n-2

8- A compound with the formula C6H6 is :

A) hexane

B) pentene

C) 3-methylButane

D) Benzene

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