# Chemistry In Our Everyday Life

# CHE 101: GENERAL CHEMISTRY
# Section 6

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***Chemistry*** is the study of:

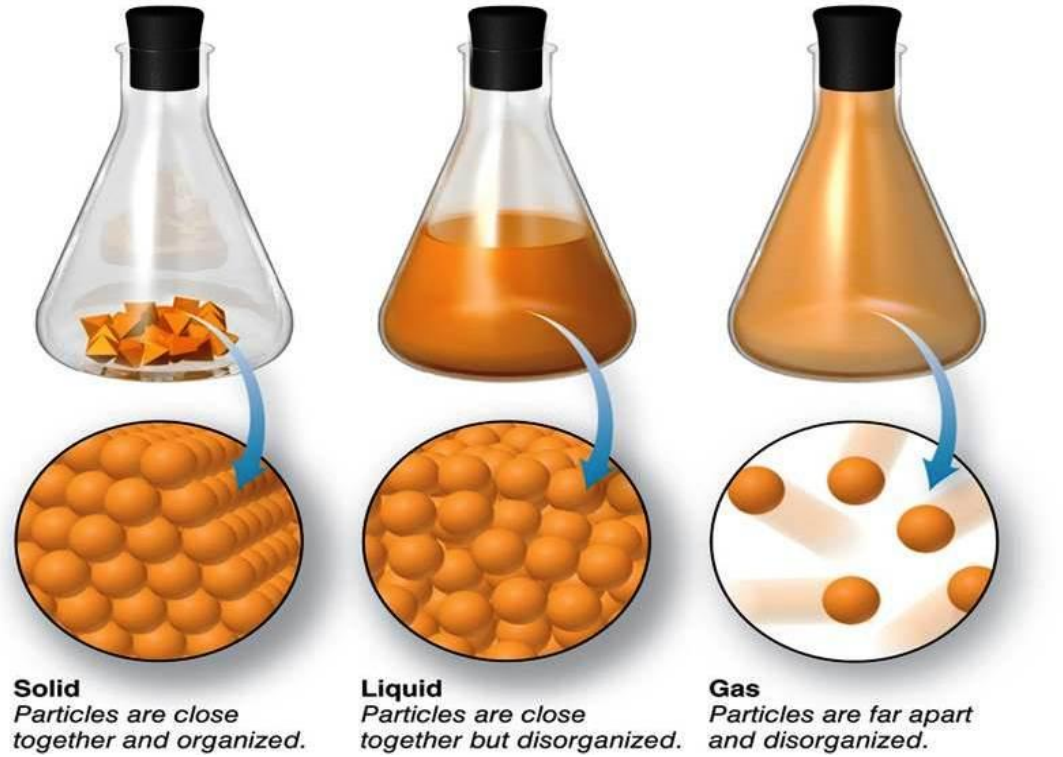
- ***matter***,
- its ***properties***,
- the ***changes*** that matter undergoes,
- and the ***energy*** associated with these changes.

# The Three States of Matter

- A ***solid*** has a fixed shape and volume. Solids may be hard or soft, rigid or flexible.

- A ***liquid*** has a varying shape that conforms to the shape of the container, but a fixed volume. ***Liquids are virtually incompressible***.

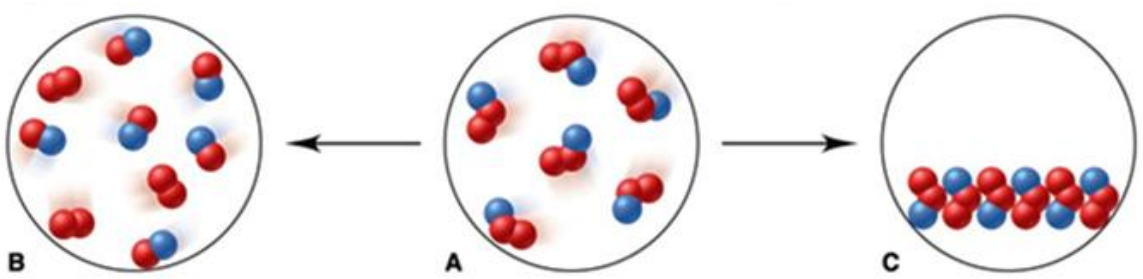
- A ***gas*** has no fixed shape or volume, and therefore does not have a surface.



# Changing State by Altering Temperature

- A ***physical change*** is a change of state. *e.g.* Solid to Liquid, or Liquid to Gas. These changes are easily reversible by altering the temperature.

- A ***chemical change*** cannot simply be reversed by altering the temperature. A change in the chemical composition describes a chemical change.




**A to B → Chemical Change**

**A to C → Physical Change**

# Chapter 1 Heat.exe

# Units and Conversion Factors

# SI (*System International*) Units

| Physical Quantity | Unit Name | Unit Abbreviation |
|---|---|---|
| Mass | kilogram | kg |
| Length | meter | m |
| Time | second | s |
| Temperature | kelvin | K |
| Electric Current | ampere | A |
| Amount of substance | mole | mol |

**Table 1.4 Common SI-English Equivalent Quantities**

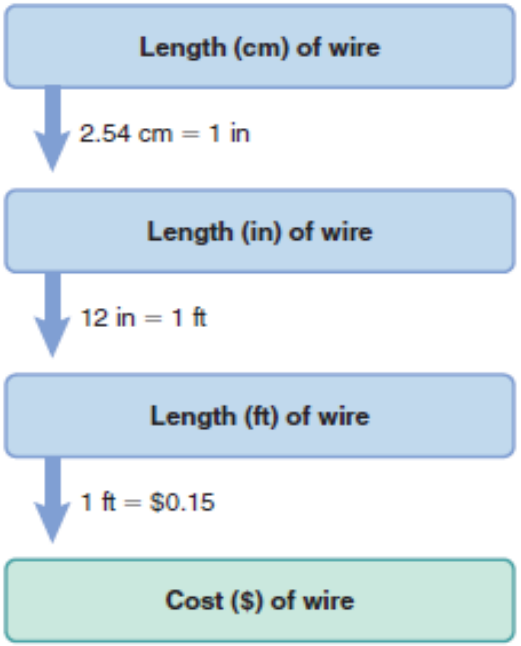
| Quantity | SI | SI Equivalents | English Equivalents | English to SI Equivalent |
|---|---|---|---|---|
| Length | 1 kilometer (km) | 1000 ($10^3$) meters | 0.6214 mile (mi) | 1 mile = 1.609 km |
| | 1 meter (m) | 100 ($10^2$) centimeters | 1.094 yards (yd) | 1 yard = 0.9144 m |
| | | 1000 millimeters (mm) | 39.37 inches (in) | 1 foot (ft) = 0.3048 m |
| | 1 centimeter (cm) | 0.10 ($10^{-2}$) meter | 0.3937 inch | 1 inch = 2.54 cm (exactly) |
| Volume | 1 cubic meter ($m^3$) | 1,000,000 ($10^6$) cubic centimeters | 35.31 cubic feet ($ft^3$) | 1 cubic foot = 0.02832 $m^3$ |
| | 1 cubic decimeter ($dm^3$) | 1000 cubic centimeters | 0.2642 gallon (gal) | 1 gallon = 3.785 $dm^3$ |
| | | | 1.057 quarts (qt) | 1 quart = 0.9464 $dm^3$ |
| | | | | 1 quart = 946.4 $cm^3$ |
| | 1 cubic centimeter ($cm^3$) | 0.001 $dm^3$ | 0.03381 fluid ounce | 1 fluid ounce = 29.57 $cm^3$ |
| Mass | 1 kilogram (kg) | 1000 grams (g) | 2.205 pounds (lb) | 1 pound = 0.4536 kg |

# Conversion Factors

**Sample Problem 1.3**

To wire your stereo equipment, you need 325 centimeters (cm) of speaker wire that sells for $0.15/ft. What is the price of the wire?

**Road Map**



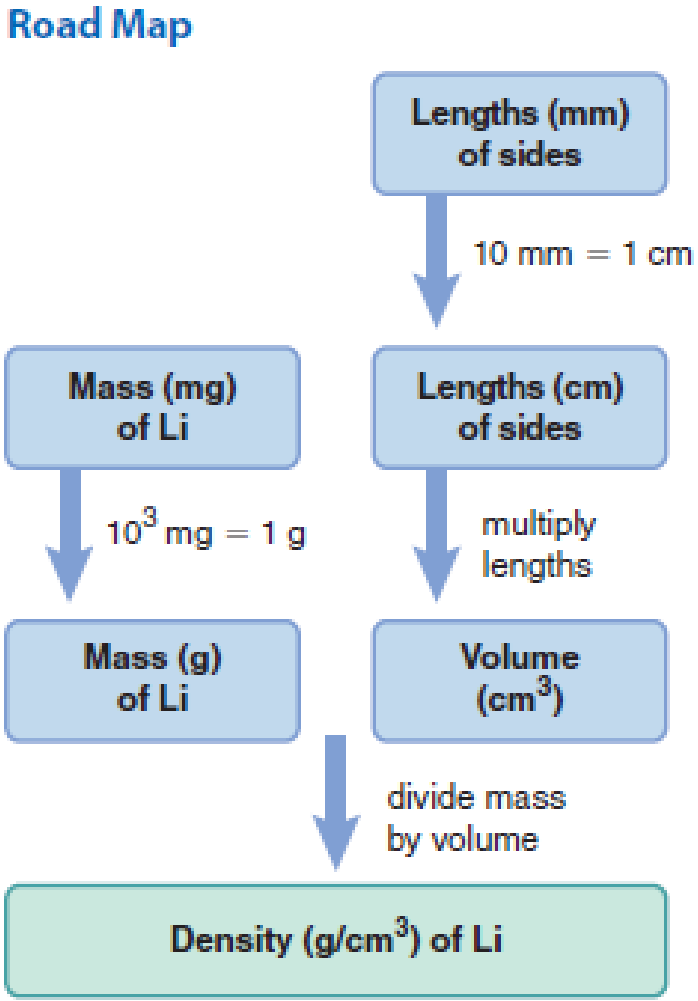
# Density

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

**Sample Problem 1.7**

Lithium, a soft, gray solid with the lowest density of any metal, is a key component of advanced batteries. A slab of lithium weighs $1.49 \times 10^3$ mg and has sides that are 20.9 mm by 11.1 mm by 11.9 mm. Find the density of lithium in **g/cm$^3$**.

Hints




**Ans: 0.540 $g/cm^3$**

# Elements, Molecules, and Compounds

**Element -** The simplest type of substance with unique physical and chemical properties. ***An element consists of only one type of atom***.

A Atoms of an element

**Molecule -** A structure that consists of two or more atoms that are ***chemically*** bound together and thus behaves as an independent unit.

B Molecules of an element

**Compound** – A substance composed of two or more elements that are ***chemically*** combined.

C Molecules of a compound

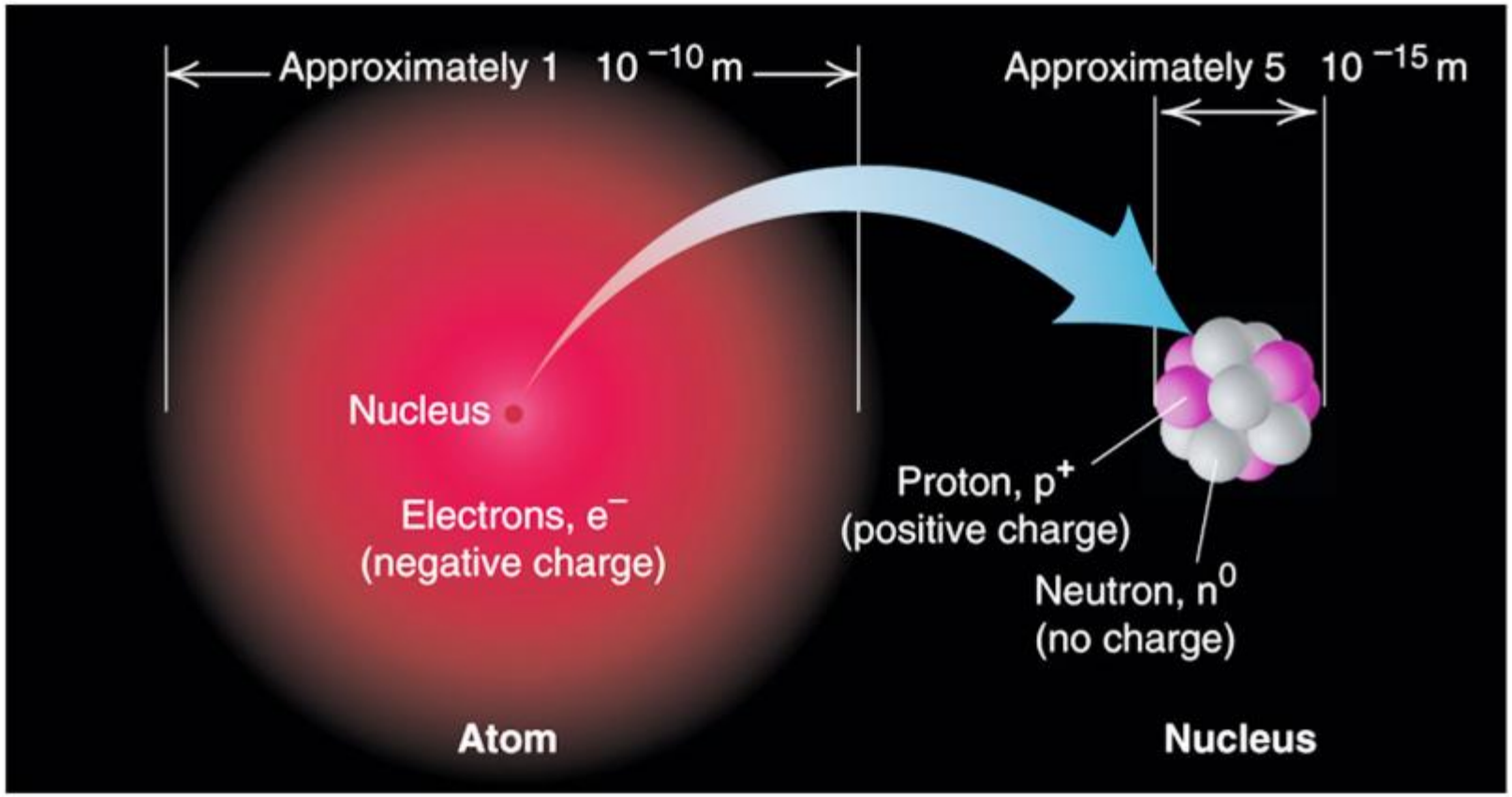
**Mixture** – A group of two or more elements and/or compounds that are ***physically*** intermingled.

D Mixture of two elements and a compound

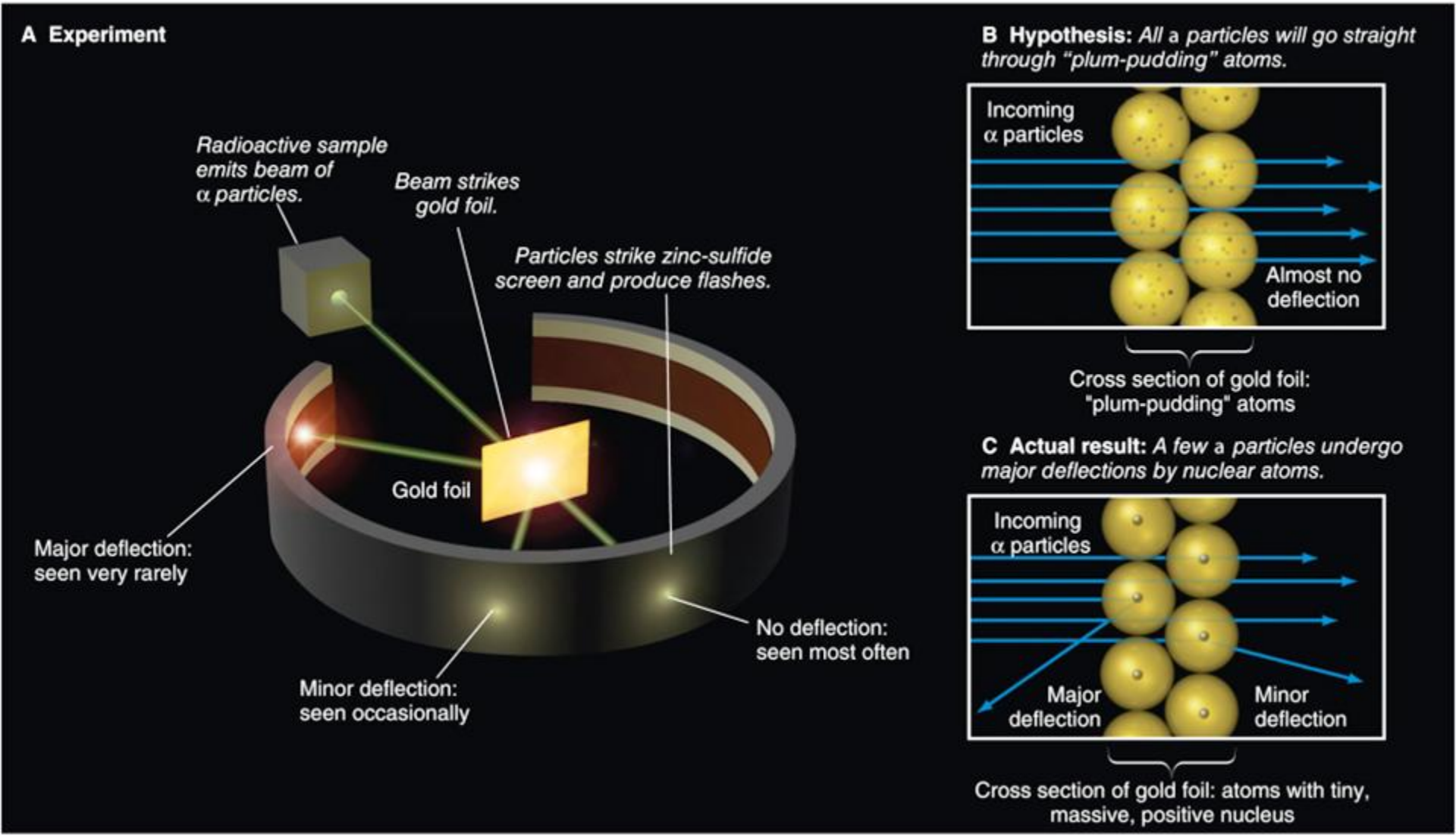
# A Closer Look into an Atom

- The ***atom*** is an electrically neutral, spherical entity composed of a positively charged central nucleus surrounded by one or more negatively charged ***electrons***.

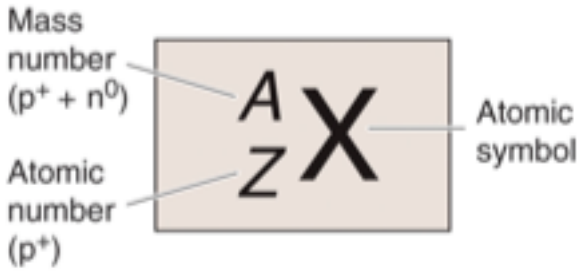
- The ***nucleus*** at the center of an atom consists of ***protons*** and ***neutrons***.



# Rutherford's α-scattering experiment that led to the discovery of the Nucleus



# Atomic Symbol, Number, and Mass

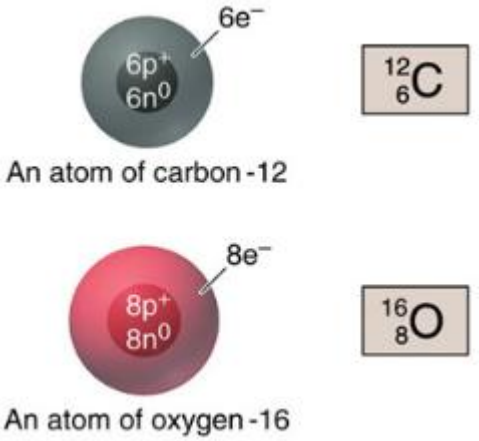



**X =** atomic symbol of the element

***Z* =** atomic number
(number of protons in the nucleus)

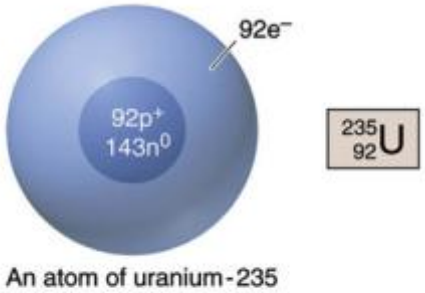
***N* =** number of neutrons in the nucleus

***A* =** mass number; ***A = Z + N***



# Isotopes

- **Isotopes** are atoms of an element with the same ***atomic number***, but different ***mass number***.
- In other words, isotopes have the same number of ***protons***, but different number of ***neutrons***.



## Sample Problem 2.4

Silicon (Si) has three naturally occurring isotopes: $^{28}Si$, $^{29}Si$, and $^{30}Si$. Determine the number of ***protons***, ***neutrons***, and ***electrons*** in each silicon isotope.

**SOLUTION** The atomic number of silicon is 14; therefore

**$^{28}Si$ has $14p^+$, $14e^-$, and $14n^0$ (28 – 14 = 14)**

**$^{29}Si$ has $14p^+$, $14e^-$, and $15n^0$ (29 – 14 = 15)**

**$^{30}Si$ has $14p^+$, $14e^-$, and $16n^0$ (30 – 14) = 16**

## Some more problems to play with...

1. Find the number of protons, electrons and neutrons in $Na^{+}$, $Ca^{2+}$ and $S^{2-}$.

$$\text{Number of neutrons} = \text{mass number} - \text{atomic number}, \quad \text{or} \quad N = A - Z$$

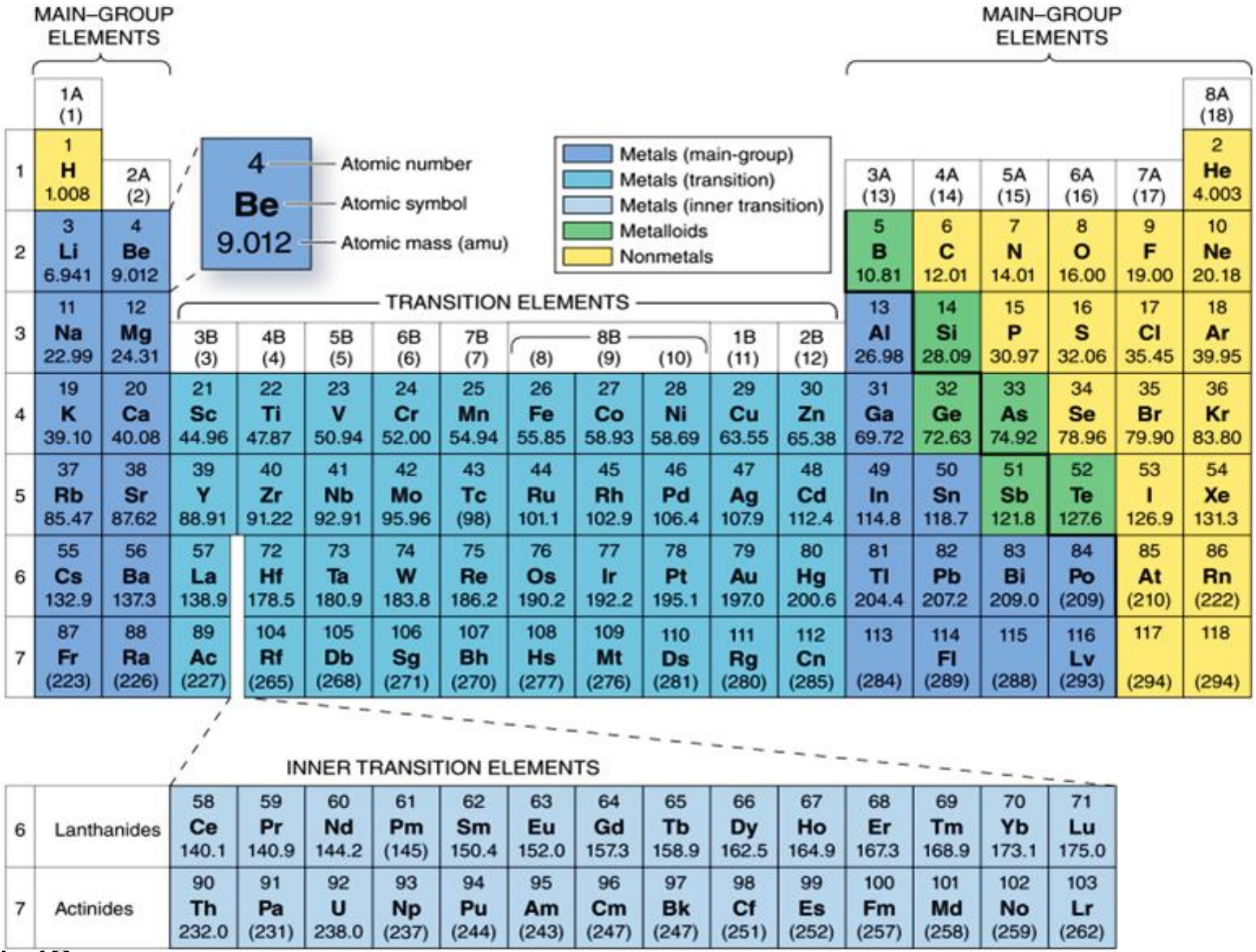
2. The species $X^{3+}$ contains 10 electrons. Which element is X?

Next class

# Periodic Table and Ionic Charge

# Properties

- In the periodic table, the elements are arranged by atomic number into horizontal periods and vertical groups.
- Nonmetals appear in the upper-right portion of the table, metalloids lie along a staircase line, and metals fill the rest of the table.
- Elements within a group have similar behavior, whereas elements within a period have dissimilar behavior.

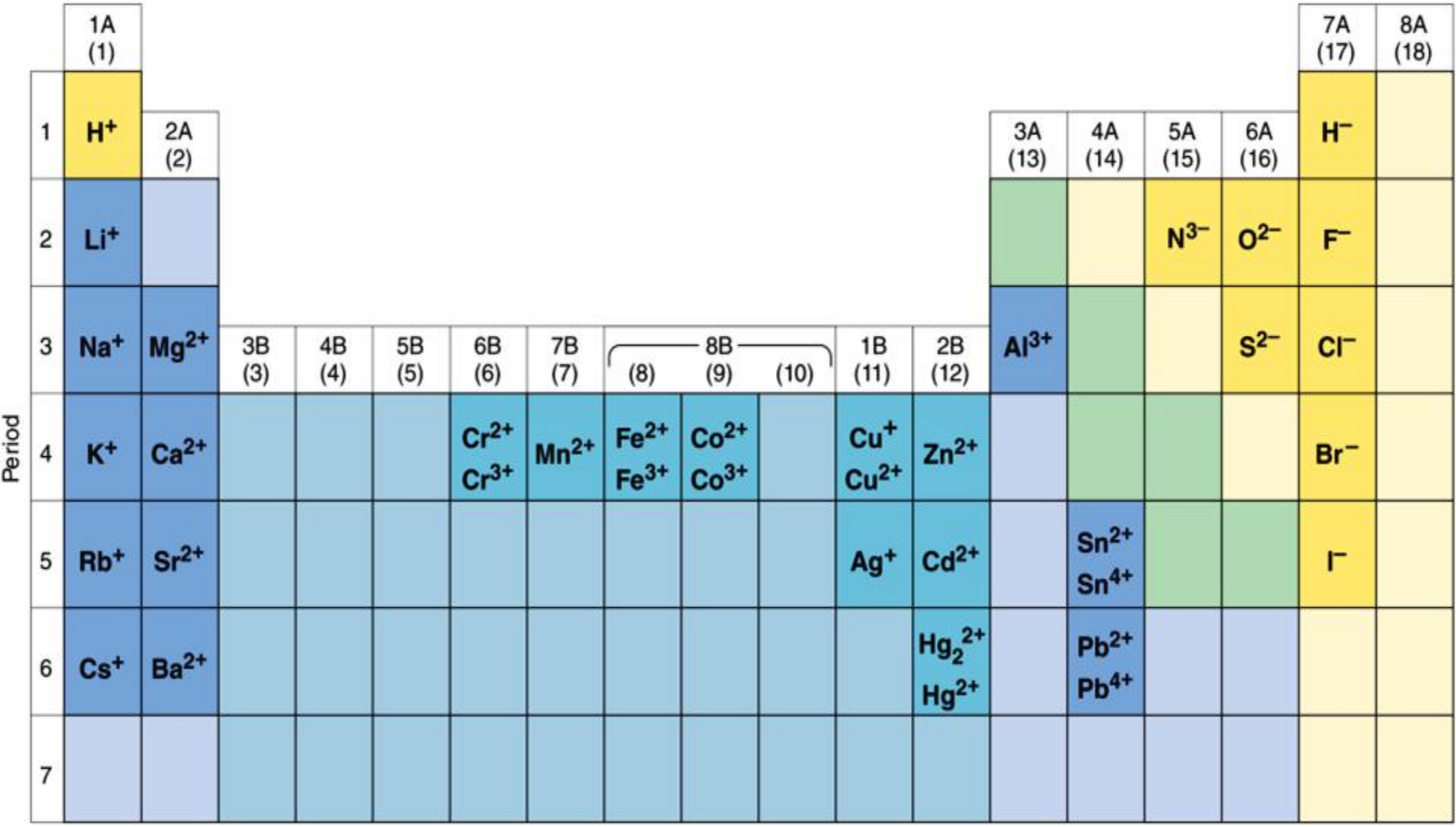

MAIN–GROUP ELEMENTS
MAIN–GROUP ELEMENTS
TRANSITION ELEMENTS
INNER TRANSITION ELEMENTS
Period
4
Be
9.012
Atomic number
Atomic symbol
Atomic mass (amu)
Metals (main-group)
Metals (transition)
Metals (inner transition)
Metalloids
Nonmetals
1A (1)
2A (2)
3A (13)
4A (14)
5A (15)
6A (16)
7A (17)
8A (18)
3B (3)
4B (4)
5B (5)
6B (6)
7B (7)
8B (8) (9) (10)
1B (11)
2B (12)
1 H 1.008
2 He 4.003
3 Li 6.941
4 Be 9.012
5 B 10.81
6 C 12.01
7 N 14.01
8 O 16.00
9 F 19.00
10 Ne 20.18
11 Na 22.99
12 Mg 24.31
13 Al 26.98
14 Si 28.09
15 P 30.97
16 S 32.06
17 Cl 35.45
18 Ar 39.95
19 K 39.10
20 Ca 40.08
21 Sc 44.96
22 Ti 47.87
23 V 50.94
24 Cr 52.00
25 Mn 54.94
26 Fe 55.85
27 Co 58.93
28 Ni 58.69
29 Cu 63.55
30 Zn 65.38
31 Ga 69.72
32 Ge 72.63
33 As 74.92
34 Se 78.96
35 Br 79.90
36 Kr 83.80
37 Rb 85.47
38 Sr 87.62
39 Y 88.91
40 Zr 91.22
41 Nb 92.91
42 Mo 95.96
43 Tc (98)
44 Ru 101.1
45 Rh 102.9
46 Pd 106.4
47 Ag 107.9
48 Cd 112.4
49 In 114.8
50 Sn 118.7
51 Sb 121.8
52 Te 127.6
53 I 126.9
54 Xe 131.3
55 Cs 132.9
56 Ba 137.3
57 La 138.9
72 Hf 178.5
73 Ta 180.9
74 W 183.8
75 Re 186.2
76 Os 190.2
77 Ir 192.2
78 Pt 195.1
79 Au 197.0
80 Hg 200.6
81 Tl 204.4
82 Pb 207.2
83 Bi 209.0
84 Po (209)
85 At (210)
86 Rn (222)
87 Fr (223)
88 Ra (226)
89 Ac (227)
104 Rf (265)
105 Db (268)
106 Sg (271)
107 Bh (270)
108 Hs (277)
109 Mt (276)
110 Ds (281)
111 Rg (280)
112 Cn (285)
113 (284)
114 Fl (289)
115 (288)
116 Lv (293)
117 (294)
118 (294)
6 Lanthanides
58 Ce 140.1
59 Pr 140.9
60 Nd 144.2
61 Pm (145)
62 Sm 150.4
63 Eu 152.0
64 Gd 157.3
65 Tb 158.9
66 Dy 162.5
67 Ho 164.9
68 Er 167.3
69 Tm 168.9
70 Yb 173.1
71 Lu 175.0
7 Actinides
90 Th 232.0
91 Pa (231)
92 U 238.0
93 Np (237)
94 Pu (244)
95 Am (243)
96 Cm (247)
97 Bk (247)
98 Cf (251)
99 Es (252)
100 Fm (257)
101 Md (258)
102 No (259)
103 Lr (262)

# Properties

- Group 1A(1), except for hydrogen, consists of the *alkali metals, and Group 2A(2) consists of the alkaline earth metals. Both groups consist of highly reactive elements. The halogens,*

- Group 7A(17), are highly reactive nonmetals, whereas the *noble gases, Group 8A(18),* are relatively un-reactive nonmetals.
- Other main groups [3A(13) to 6A(16)] are often named for the first element in the group; for example, Group 6A(16) is the *oxygen family.*

# Common Ions Related to the Group Numbers



# A closer look

- *Metals lose electrons: elements in Group 1A(1) lose one electron, elements in* Group 2A(2) lose two, and aluminum in Group 3A(13) loses three.

- *Nonmetals gain electrons: elements in Group 7A(17) gain one electron,*

- *Oxygen* and sulfur in Group 6A(16) gain two, and nitrogen in Group 5A(15) gains three

# Naming
# Let's begin with two general rules:

- For *all ionic compounds, names and formulas give the positive ion (cation) first and the negative ion (anion) second.*
- **For all ''*binary'' ionic*** *compounds, the name of the cation is the name of the metal, and the name of the anion has the suffix -ide added to the root of the name of the nonmetal.*

e.g anion formed from brom*ine is named bromide (brom1ide),* the compound formed from the calcium and the bromine is named *calcium bromide*


**Table 2.3 Common Monatomic Ions***

| Charge | Formula | Name |
|---|---|---|
| **Cations** | | |
| 1+ | $H^+$ | hydrogen |
| | **$Li^+$** | **lithium** |
| | **$Na^+$** | **sodium** |
| | **$K^+$** | **potassium** |
| | $Cs^+$ | cesium |
| | **$Ag^+$** | **silver** |
| 2+ | **$Mg^{2+}$** | **magnesium** |
| | **$Ca^{2+}$** | **calcium** |
| | $Sr^{2+}$ | strontium |
| | **$Ba^{2+}$** | **barium** |
| | **$Zn^{2+}$** | **zinc** |
| | $Cd^{2+}$ | cadmium |
| 3+ | $Al^{3+}$ | aluminum |
| **Anions** | | |
| 1− | $H^-$ | hydride |
| | **$F^-$** | **fluoride** |
| | **$Cl^-$** | **chloride** |
| | **$Br^-$** | **bromide** |
| | **$I^-$** | **iodide** |
| 2− | **$O^{2-}$** | **oxide** |
| | **$S^{2-}$** | **sulfide** |
| 3− | $N^{3-}$ | nitride |

*Listed by charge; those in **boldface** are most common.

# Monatomic ions of elements

- Monatomic ions of elements in the same main group have the same ionic charge; the alkali metals—Li, Na, K, Rb, Cs, and Fr—( all have 1+ charge) .
- E.g Cations, ion charge equals A-group number: Na is in Group 1A and forms Na +, Ba is in Group 2A and forms Ba2+. **(Exceptions in Figure 2.17 are Sn2+ and Pb2+.)**
- For anions, ion charge equals A-group number minus 8; for example, S is in Group 6A (6 - 8 )= -2) and thus forms S2-.

# Compounds of Metals That Form More Than one Ion

- Names of compounds containing these elements include a *Roman numeral within parentheses* immediately after the metal ion's name to indicate its ionic charge.
- For example, iron can form Fe2+ and Fe3+ ions. Iron forms two compounds with chlorine:
- FeCl2, named iron(II) chloride (spoken "iron two chloride"), which contains Fe2+; and
- FeCl3, named iron(III) chloride, which contains Fe3+

# Compounds of Metals That Form More Than one Ion

- In common names for certain metal ions, the Latin root of the metal is followed by either of two suffixes
- The suffix *-ous for the ion with the lower charge*
- The suffix *-ic for the ion with the higher charge*

Thus, iron(II) chloride is also called ferr*ous chloride and iron(III) chloride is fer ric* chloride.

(Memory aid: there is an ***o in -ous and lower, and an i in -ic and higher.)***

# Compounds of Metals That Form More Than one Ion

**Table 2.4 Some Metals That Form More Than One Monatomic Ion***

| Element | Ion Formula | Systematic Name | Common (Trivial) Name |
|---|---|---|---|
| Chromium | $Cr^{2+}$ | chromium(II) | chromous |
| | **$Cr^{3+}$** | **chromium(III)** | chromic |
| Cobalt | $Co^{2+}$ | cobalt(II) | |
| | $Co^{3+}$ | cobalt(III) | |
| Copper | **$Cu^{+}$** | **copper(I)** | cuprous |
| | **$Cu^{2+}$** | **copper(II)** | cupric |
| Iron | **$Fe^{2+}$** | **iron(II)** | ferrous |
| | **$Fe^{3+}$** | **iron(III)** | ferric |
| Lead | **$Pb^{2+}$** | **lead(II)** | |
| | $Pb^{4+}$ | lead(IV) | |
| Mercury | $Hg_2^{2+}$ | mercury(I) | mercurous |
| | **$Hg^{2+}$** | **mercury(II)** | mercuric |
| Tin | **$Sn^{2+}$** | **tin(II)** | stannous |
| | $Sn^{4+}$ | tin(IV) | stannic |

*Listed alphabetically by metal name; the ions in **boldface** are most common.

## Sample Problem 2.8

Name the ionic compound formed from each of the following pairs of elements:

**(a)** magnesium and nitrogen **(b)** iodine and cadmium

**(c)** strontium and fluorine **(d)** sulfur and cesium

**Plan** The key to naming a binary ionic compound is to recognize which element is the metal and which is the nonmetal. When in doubt, check the periodic table. We place the cation name first, add the suffix *-ide* to the nonmetal root, and place the anion name last.

## Sample Problem 2.9

Write empirical formulas for each of the above compounds.

# Molecular Masses from Chemical Formulas

- **Molecular Mass = Sum of Atomic Masses**

**For the $H_2O$ molecule,**

Molecular mass = (2 × atomic mass of H) + (1 × atomic mass of O)

= (2 × 1.008 amu) + (1 × 16.00 amu)

= 18.02 amu

- **Molar Mass = Molecular Mass in grams**

**1 mole of $H_2O$ has a mass of 18.02 grams

*****1 mole of $H_2O$ contains **$6.022 \times 10^{23}$** $H_2O$ molecules (***Avogadro Number***)