COURSE - MINT CHEMISTRY

TOPIC 4
SI Units; Content, Proportion, Concentration

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LEARNING OUTCOMES

Knowing the quantities of a substance and converting between them.

Determine the molar masses of substances.

Assign, calculate and convert the different specifications of content.

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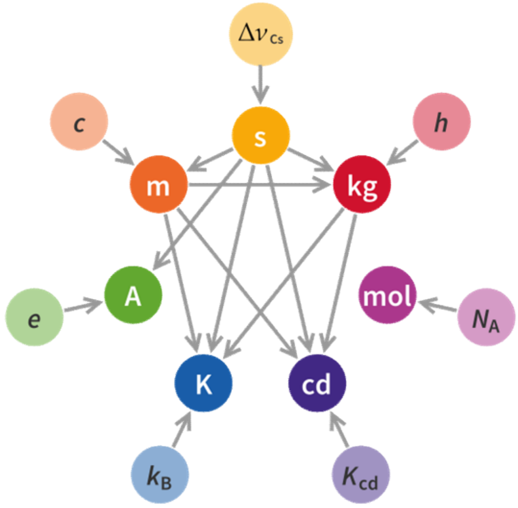
Dependency of Units and Constants



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Definition (Length)
Quantity symbol: *l*
Dimension symbol: L

Definition:
The meter, unit symbol m, is the SI unit of length. It is defined by the speed of light in a vacuum, *c*, with the determined numerical value of 299 792 458, expressed in the unit m/s, with the second being defined by $\Delta\nu_{Cs}$.

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Definition (Mass)
Quantity symbol: *m*
Dimension symbol: M

kg

Definition:
The kilogram, unit symbol kg, is the SI unit of mass. It is defined by the Planck constant, *h*, with the determined numerical value of 6.626 070 15 × 10^{-34}, expressed in the unit J s, which is equal to kg m^2 s^{-1}, where the meter and second are defined by *c* and $\Delta\nu_{Cs}$.

The kilogram (kg) is the ONLY COHERENT SI UNIT with a prefix

Definition (Time)
Quantity symbol: *t*
Dimension symbol: T

s

Definition:
The second, unit symbol s, is the SI unit of time. It is defined by the cesium frequency $\Delta\nu_{Cs}$, the frequency of the unperturbed hyperfine transition of the ground state of cesium atom 133, of 9 192 631 770, expressed in units of Hz, which is equal to s^{-1}.

Definition (Electrical current)
Quantity symbol: *I*
Dimension symbol: I

Definition:
The ampere, unit symbol A, is the SI unit of electric current. It is defined by the elementary charge, *e*, with the determined numerical value 1.602 176 634 × 10$^{−19}$, expressed in units C, which is equal to A s, where the second is defined by Δν_{Cs}.

Definition (Temperature)
Quantity symbol: *T*
Dimension symbol: Θ

Definition:
The Kelvin, unit symbol K, is the SI unit of thermodynamic temperature. It is defined by the Boltzmann constant, *k*, with the determined numerical value 1.380 649 × 10^{-23}, expressed in the unit J K^{-1}, which is equal to kg m^{2} s^{-2} K^{-1}, where the kilogram, the meter and the second are defined by *h*, *c* and Δν_{Cs}.

Definition (Amount of substance)
Quantity symbol: *n*
Dimension symbol: N

mol

Definition:
The mol, unit symbol mol, is the SI unit of amount of substance. One mole contains exactly 6.022 140 76 × 10^{23} individual particles. This number corresponds to the fixed numerical value applicable to the Avogadro constant N_A, expressed in units of mol^{-1}, and is known as the Avogadro number. The amount of substance, sign *n*, of a system is a measure of a number of specified constituents. A single particle can be an atom, a molecule, an ion, an electron, another particle or a group of such particles with specified composition.

Definition (Luminosity)
Quantity symbol: I_V
Dimension symbol: J

cd

Definition:
The candela, unit symbol cd, is the SI unit of luminous intensity in a given direction. It is defined by the determined numerical value 683 for the photometric radiation equivalent K_{cd} of monochromatic radiation of frequency 540 × 10^{12} Hz, expressed in the unit lm W^{-1}, which is equal to cd sr W^{-1} or cd sr kg^{-1} m^{-2} s^3, where the kilogram, meter, and second are defined in terms of *h*, *c*, and $\Delta\nu_{Cs}$.

SI Prefixes for Decimal Multiples

Power	Name	Symbol	Numerical value
10^{24}	Yotta	Y	1 000 000 000 000 000 000 000 000
10^{21}	Zetta	Z	1 000 000 000 000 000 000 000
10^{18}	Exa	E	1 000 000 000 000 000 000
10^{15}	Peta	P	1 000 000 000 000 000
10^{12}	Tera	T	1 000 000 000 000
10^{9}	Giga	G	1 000 000 000
10^{6}	Mega	M	1 000 000
10^{3}	Kilo	k	1 000
10^{2}	Hecto	h	100
10^{1}	Deca	da	10
10^{-1}	Deci	d	0.1
10^{-2}	Centi	c	0.01
10^{-3}	Milli	m	0.001
10^{-6}	Micro	µ	0.000 001
10^{-9}	Nano	n	0.000 000 001
10^{-12}	Pico	p	0.000 000 000 001
10^{-15}	Femto	f	0.000 000 000 000 001
10^{-18}	Atto	a	0.000 000 000 000 000 001
10^{-21}	Zepto	z	0.000 000 000 000 000 000 001
10^{-24}	Yocto	y	0.000 000 000 000 000 000 000 001

A (coherent) SI unit with a prefix gives a NON-coherent SI unit.

The kilogram (kg) is the ONLY COHERENT SI UNIT with a prefix.

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Derived SI Units

Name	Symbol	Quantity	in SI base units	in other SI units
Becquerel	Bq	Radioactivity	s^{-1}	
Celcius	°C	Temperature relative to 273.15 K	K	
Coulomb	C	Electrical charge	A · s	
Farad	F	Electrical capacity	$m^2\ kg^{-1}\ s^4\ A^2$	C/V
Gray	Gy	Absorbed dose	$m^2\ s^{-2}$	J/kg
Henry	H	Inductance	$m^2\ kg\ s^{-2}\ A^{-2}$	Wb/A
Hertz	Hz	Frequency	s^{-1}	
Joule	J	Energy, Work, Thermal energy	$m^2\ kg\ s^{-2}$	N m; W s
Katal	kat	Catalytic activity	$mol\ s^{-1}$	
Lumen	lm	Luminosity	cd	cd sr
Lux	Lx	Illuminance	m^2 cd	lm/m^2
Newton	N	Force	$m\ kg\ s^{-2}$	J/m
Ohm	Ω	Electrical resistance	$m^2\ kg\ s^{-3}\ A^{-2}$	V/A
Pascal	Pa	Pressure	$m^{-1}\ kg\ s^{-2}$	N/m^2
Radiant	Rad	Plane angle	1	m/m
Siemens	S	Electrical conductance	$m^{-2}\ kg^{-1}\ s^3\ A^2$	1/Ω
Sievert	Sv	Equivalent dose	$m^2\ s^{-2}$	J/kg
Steratiant	sr	Solid angle	1	m^2/m^2
Tesla	T	Magnetic flux density	$kg\ s^{-2}\ A^{-1}$	Wb/m^2
Watt	W	Power	$m^2\ kg\ s^{-3}$	J/s; V A
Weber	Wb	Magnetic flux	$m^2\ kg\ s^{-2}\ A^{-1}$	Vs
Volt	V	Electrical voltage	$M^2\ kg\ s^{-3}\ A^{-1}$	W/A; J/C

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DERIVED SI UNITS (Examples)

1 Cubic metre (m^3)
is the **volume** (cubic measure) of a cube of 1 m length, 1 m width and 1 m height

The litre unit is not an SI unit, but is permitted in use in SI. The unit symbol is "*l*".

It CAN also be written as "*L*" because it can be confused with I (*l*) or the digit 1 (in English-speaking countries) when using a sans serif font.

The capital "*L*" was approved by the CGPM as an alternative unit symbol for the litre. ISO and IEC only use the original unit symbol "*l*". IUPAC and DIN 1301-1 allow both spellings.

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DERIVED SI UNITS (Examples)

1 Newton (N)
is the **force** acting on a 1 kg body accelerated at 1 m/s^2:

1 N = 1 kg m/s^2

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DERIVED SI UNITS (Examples)

1 Pascal (Pa)
is the **pressure** exerted by a force of 1 N
on an area of 1 m2.

1 Pa = 1 N/m² = 1 (kg m)/(m² s²)

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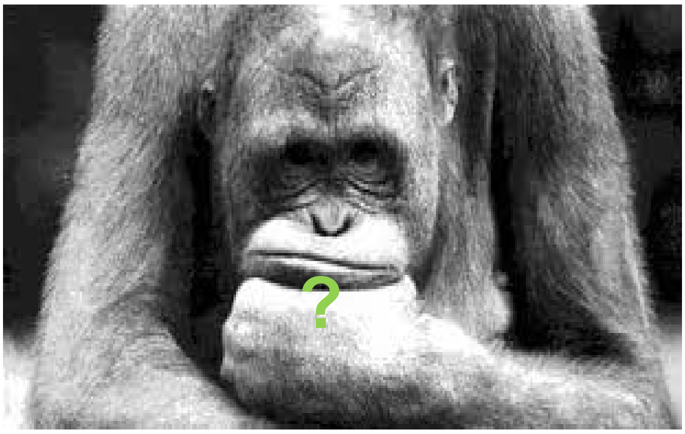
https://fbr.io/join/tfcuz



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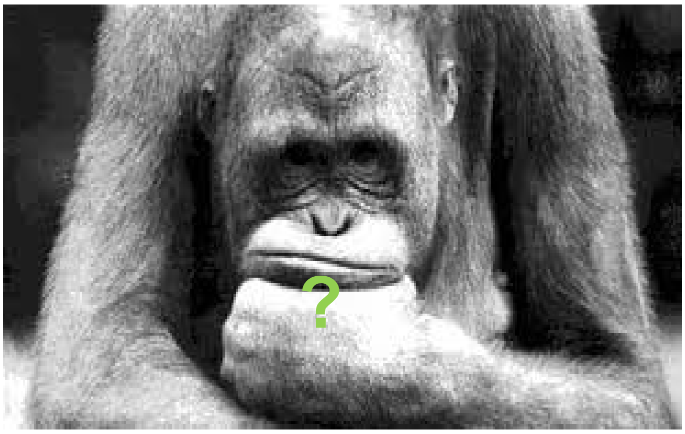
How can I indicate how much of a substance is present?



QUANTITIES

QUANTITIES

Define "how much" of a **substance** is present:

Quantity	Quantity Symbol*	Dimension Symbol	Unit	Associated SI Unit

QUANTITIES

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Define "how much" of a **substance** is present:

Quantity	Quantity Symbol*	Dimension Symbol	Unit	Associated SI Unit
VOLUME				
AMOUNT OF SUBSTANCE				
MASS				

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QUANTITIES

QUANTITIES

Define "how much" of a **substance** is present:

Quantity	Quantity Symbol*	Dimension Symbol	Unit	Associated SI Unit
VOLUME	V	V	m^3	m
AMOUNT OF SUBSTANCE	n	N	mol	mol
MASS	m	M	kg	kg

Note:
Quantity symbols are always associated with a quantity (number).
Quantity symbols are ALWAYS in italics.

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CONTENT QUANTITIES

QUANTITIES

Define "how much" of a **substance** is present:

Quantity	Quantity Symbol*	Dimension Symbol	Unit	Associated SI Unit
VOLUME	*V*	V	m^3	m
AMOUNT OF SUBSTANCE	*n*	N	mol	mol
MASS	*m*	M	kg	kg

Each base quantity is assigned a dimension with the same name.
For example, in the International System of Quantities (ISQ), the dimension of the base quantity mass is also called mass. A quantity is symbolized with a letter written in italics (**quantity symbol**) – in the case of mass with “***m***”.
The **symbol of a dimension**, on the other hand, is an upright sans serif capital letter – in the case of mass, “**M**”.
The corresponding **coherent unit** of mass is the kilogram (**kg**).

CONTENT QUANTITIES

QUANTITIES

Define "how much" of a **substance** is present:

Quantity	Quantity Symbol*	Dimension Symbol	Unit	Associated SI Unit
VOLUME	*V*	V	m^3	m
AMOUNT OF SUBSTANCE	*n*	N	mol	mol
MASS	*m*	M	kg	kg

Convert from ***m*** **to** ***V*** **via the densitiy (*ρ*)**:

$$\rho = \frac{m}{V} \text{ [g/mL]}$$

EXAMPLE 4.1

- Calculate the mass of 0.100 L of a solution that has a density of 1.10 g/mL.

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- Calculate the mass of 0.100 L of a solution that has a density of 1.10 g/mL.

$$\rho = \frac{m}{V} \text{ [g/mL]}$$

m = 1.10 g/ml x 100 mL = 110 g

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GEHALTSGRÖßEN

MENGENGRÖßEN

Define "how much" of a **substance** is present:

Quantity	Quantity Symbol*	Dimension Symbol	Unit	Associated SI Unit
VOLUME	*V*	V	m^3	m
AMOUNT OF SUBSTANCE	*n*	N	mol	mol
MASS	*m*	M	kg	kg

Convert from ***m* to *n* via the molar mass (*M*)**:

$$M = \frac{m}{n}\ [\text{g/mol}]$$

Revision: THE MOLE...

The number of particles corresponds to **6,022** 140 76 **x 10^{23}** particles.

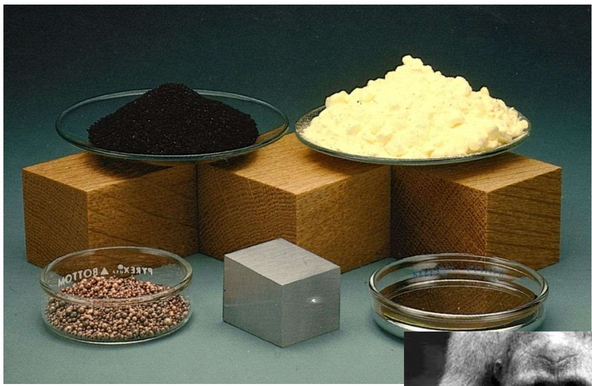
The quantity is called the **Avogadro number** (N_A)

Thus the amount of substance of 1 mol has exactly 6.02214076 x 10^{23} particles (=natural constant)

Each of these samples consists of 1 mole of the element

Clockwise from top right:

32.065 g	Sulphur
200.59 g	Mercury
207.2 g	Lead
63.546 g	Copper
12.011 g	Carbon

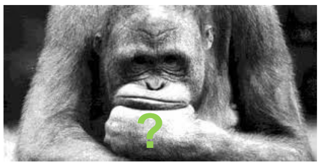


...how many atoms are there in each?
...and it's 6.02214076 x 10^{23} atoms of that element each time

E4.1 Number of moles in a sample

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

What mass of copper is required to obtain a sample containing 1.234 moles of Cu?



E4.1 Number of moles in a sample

$M = \frac{m}{n} \rightarrow m = M \times n$

What mass of copper is required to obtain a sample containing 1.234 moles of Cu?

1 mol Cu = 63.546 g Cu => *M* = 63.546 g/mol

Hier steckt eine Schlussrechnung drinnen!

Masse *m*(Cu) (g) = *n* x *M* = 1.234 mol * 63.546 g/mol = 78.42 g Cu

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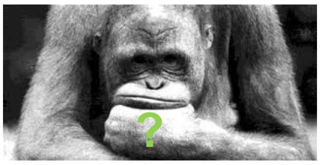
E4.2 Number of moles in a sample

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

How many moles (=what amount of substance n) does a sample of 100.0 g tin (Sn) contain?



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E4.2 Number of moles in a sample

$$M = \frac{m}{n} \rightarrow n = \frac{m}{M}$$

How many moles (=what amount of substance n) does a sample of 100.0 g tin (Sn) contain?

M(Sn) = 118.71 g/mol => 1 mol Sn = 118.71 g Sn

Number of moles (amount of substance) Sn : *n* = *m*/*M* = 100.0 g / 118.71 g/mol
= 0.8424 mol Sn

MOLAR MASS OF COMPOUNDS

NaCl | $CaCO_3$ | $FeSO_4 \times 7\ H_2O$ | Na_2O_2

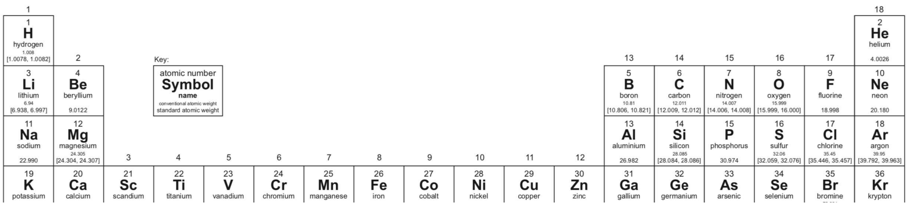
The molar masses of compounds are the sum of the molar masses of the atoms in that compound

11
Na
sodium
22.990

M (NaCl) = 22.990 + 35.45 = 58.440 = 58.44 g/mol

17
Cl
chlorine
35.45
[35.446, 35.457]

IUPAC Periodic Table of the Elements



MOLAR MASS OF COMPOUNDS

NaCl
58.44 g/mol

$CaCO_3$

$FeSO_4 \times 7\ H_2O$

Na_2O_2

M(NaCl) = M(Na)+M(Cl) = 22.990 g/mol + 35.45 g/mol = 58.44 g/mol

MOLAR MASS OF COMPOUNDS

NaCl	$CaCO_3$	$FeSO_4$ x 7 H_2O	Na_2O_2
58 g/mol	100 g/mol	278 g/mol	78 g/mol

$M(FeSO_4 \times 7\ H_2O) = M(Fe)+M(S) +4 \times M(O) + 14 \times M(H) + 7 \times M(O) =$
55.8 g/mol + 32.1 g/mol + 4 x 16.0 g/mol + 14 x 1.01 + 7 x 16.0 g/mol = 278.0 g/mol

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EXAMPLE 4.2

- Calculate the amount of substance of 20 g NaCl.

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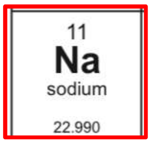
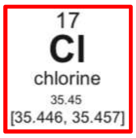
- Calculate the amount of substance of 20 g NaCl.

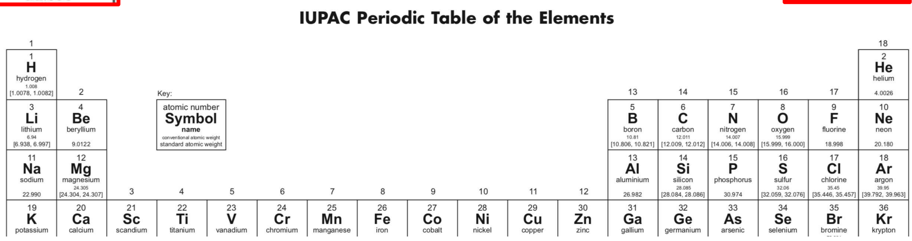
$$M = \frac{m}{n}\ [\text{g/mol}]$$



M (NaCl) = 22.990 + 35.45 = 58.440 = 58.44 g/mol

n = (20 g) / (58.44 g/mol) = 0.34223 = 0.34 mol

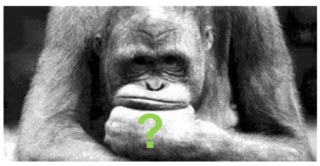




E4.3 (Mortimer 3.2)

- 0.2500 moles of sulphuric acid (H_2SO_4) are required.

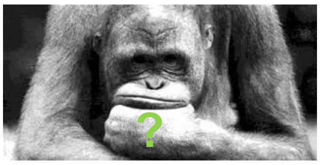
How many grams must be weighed for this?



E4.3

0.2500 moles of sulphuric acid (H_2SO_4) are required.
How many grams must be weighed for this?

1 mol of sulphuric acid $M(H_2SO_4)$ = 98.07 g/mol
Given $n = m/M$, it follows that $m = M \times n = 98.07 \times 0.2500 = 24.52$ g



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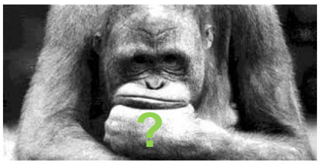
E4.4 (Mortimer 3.3)

- What percentage of iron (Fe) is contained in iron(III) oxide (Fe_2O_3)?



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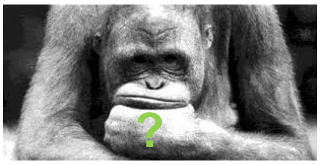
E4.4 (Mortimer 3.3)

- What percentage of iron (Fe) is contained in iron(III) oxide (Fe_2O_3)?

1 mol Fe_2O_3 contains 2 mol Fe and 3 mol O
$M(Fe_2O_3)$ = 159.687 g/mol; M(Fe) = 55.845 g/mol

That means in 159.687 g Fe_2O_3 there are 2 x 55,845 = 111,69 g Fe.

$X(Fe) = m(Fe)/m(Fe_2O_3)$ = 111.69/159.687 = 0.6994



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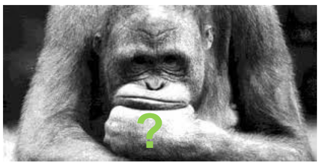
E4.5 Molar mass of compounds

$$M = \sum M_i$$

What is the mass of 1 mole of water (H_2O)?



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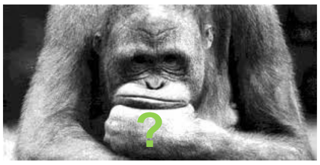
E4.5 Molar mass of compounds

$$M = \sum M_i$$

What is the mass of 1 mole of water (H_2O)?

$$M(\mathrm{H_2O}) = 2 \times M(\mathrm{H}) + M(\mathrm{O}) = 2 \times 1.008 + 15.999 = 18.015\ \mathrm{g/mol}$$



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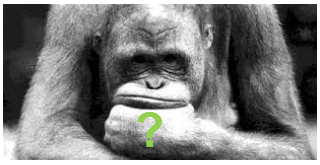
E4.6 HOW MANY moles of H_2O are in 1.000 L of water?

The density of water is approximately 1.000 kg/L



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E4.6 HOW MANY moles of H_2O are in 1.000 L of water?

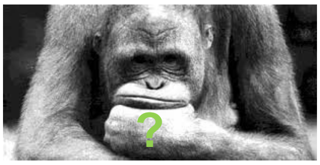
The density of water is approximately 1.000 kg/L

$m(H_2O)$ = 1.000 kg = 1000 g

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

$$n = \frac{1000\text{g/mol}}{18{,}015\text{g/mol}} = 55{,}51\text{mol}$$

In 1L of water there are 55.51 mol H_2O molecules



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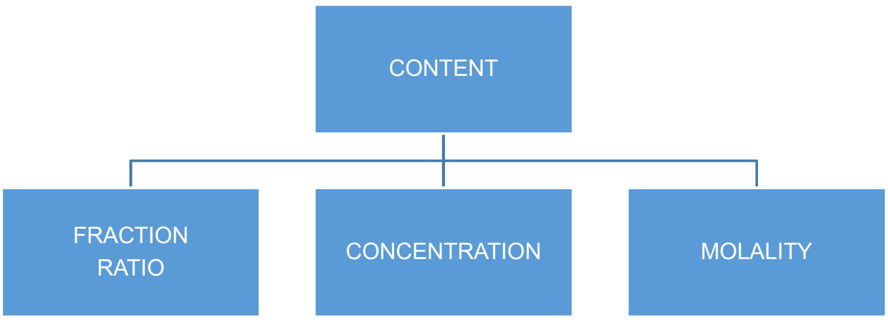
CONTENT/FRACTION/CONCENTRATION/RATIO

- **CONTENT**: indicates the quantity of a substance in a mixture
- Content quantities are physical-chemical quantities for the quantitative description of the composition of mixtures.



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CONTENT/FRACTION/CONCENTRATION/RATIO

CONTENT		Quantity of a substance	Reference Quantity	Unit
	FRACTION	n, m, V	corresponding total amount	
	RATIO	n, m, V	equivalent amount of another substance	
	CONCENTRATION	n, m, V	Total volume	
	MOLALITY	n	Mass of the solvent	

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CONTENT/FRACTION/CONCENTRATION/RATIO

CONTENT		Quantity of a substance	Reference Quantity	Unit
	FRACTION	n, m, V	corresponding total amount	
	RATIO	n, m, V	equivalent amount of another substance	
	CONCENTRATION	n, m, V	Total volume	mol/L g/L L/L
	MOLALITY	n	Mass of the solvent	mol/kg LM

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FRACTION

- **FRACTION**: Quantity of a component in relation to the sum of the same quantity of all components

  - Mass fraction
    w [g/g]

$$w(\mathrm{a}) = \frac{m_\mathrm{a}}{\sum m_\mathrm{i}}$$

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FRACTION

- **FRACTION**: Quantity of a component in relation to the sum of the same quantity of all components

  - Mass fraction
    w [g/g]

$$w(\mathrm{a}) = \frac{m_\mathrm{a}}{\sum m_\mathrm{i}}$$

  - Amount of substance fraction
    x [mol/mol]

$$x(\mathrm{a}) = \frac{n_\mathrm{a}}{\sum n_\mathrm{i}}$$

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FRACTION

- **FRACTION**: Quantity of a component in relation to the sum of the same quantity of all components

  - Mass fraction
    w [g/g]

$$w(\mathrm{a}) = \frac{m_\mathrm{a}}{\sum m_\mathrm{i}}$$

  - Amount of substance fraction
    x [mol/mol]

$$x(\mathrm{a}) = \frac{n_\mathrm{a}}{\sum n_\mathrm{i}}$$

  - Volume fraction
    φ [L/L]

$$\varphi(\mathrm{a}) = \frac{V_\mathrm{a}}{\sum V_\mathrm{i}}$$

(Remark: refers to the Volumes BEFORE mixing)

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FRACTION

- The numerical value is between 0 and 1

The fraction MAY also be specified in:

  - Percent (%) e.g. φ % (also as Vol.%) as 1 part per 100
  - Permille (‰) as 1 part per 1000
  - ppm as 1 part per 1 000 000 (million) - (part per million)
  - ppb as 1 part per 1 000 000 000 (billion) - (part per billion)
  - ppt as 1 part per 1 000 000 000 000 (trillion) - (part per trillion)
  - ppq as 1 part per 1 000 000 000 000 000 (quadrillion) – (part per quatrillion)

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FRACTION

- The numerical value is between 0 and 1

The fraction MAY also be specified in:

- Percent (%) as 1 part per 100
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- ppt as 1 part per 1 000 000 000 000 (trillion) - (part per trillion)
- ppq as 1 part per 1 000 000 000 000 000 (quadrillion) – (part per quatrillion)

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FRACTION

- The numerical value is between 0 and 1

The fraction MAY also be specified in:

- Percent (%) as 1 part per 100
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- ppm as 1 part per 1 000 000 (million) - (part per million)
- ppb as 1 part per 1 000 000 000 (billion) - (part per billion)
- ppt as 1 part per 1 000 000 000 000 (trillion) - (part per trillion)
- ppq as 1 part per 1 000 000 000 000 000 (quadrillion) – (part per quatrillion)

IUPAC does NOT recommend using these variations!

If used, state ONLY the type (w, x oder φ)

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CONCENTRATION

- **CONCENTRATION**: Quantity of a component in relation to the final volume of the mixture
  - Mass concentration
    β [g/L] (DIN: β; IUPAC: γ)

$$\beta(\mathrm{a}) = \frac{m_{\mathrm{a}}}{V_{\mathrm{mixture}}}$$

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  - Amount of substance concentration
    c [mol/L]
    $$c(\mathrm{a}) = \frac{n_\mathrm{a}}{V_\mathrm{mixture}}$$
  - Volume concentration
    σ [L/L]
    $$\sigma(\mathrm{a}) = \frac{V_\mathrm{a}}{V_\mathrm{mixture}}$$

(Remark: refers to the volumes AFTER mixing)

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RATIO

- **RATIO**: Quantity of a component relative to the same quantity of another named component
  - Mass ratio
    ζ [g/g]
    $$\zeta(\mathrm{a}) = \frac{m_\mathrm{a}}{m_\mathrm{b}}$$

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  - Amount of substance ratio R [mol/mol] $$R(\mathrm{a}) = \frac{n_{\mathrm{a}}}{n_{\mathrm{b}}}$$
  - Volume ratio ψ [L/L] $$\psi(\mathrm{a}) = \frac{V_{\mathrm{a}}}{V_{\mathrm{b}}}$$

(Remark: refers to the volume BEFORE mixing)

MOLALITY

- Molality *b* [mol/kg (solvent)]

$$b(\mathrm{a}) = \frac{n_{\mathrm{a}}}{m_{\mathrm{solvent}}}$$

(Remark: refers to the amount of substance of a substance per kg of solvent)

The molality *b* is required as a specification of content if the temperature is not constant (the volume in the specification of concentration changes with the temperature)

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Größe	Definitionsgleichung (Zweikomponentengemisch)	englisch	Größen-zeichen	Einheit (Beispiel)
Massenanteil	$w(\mathrm{A}) = \frac{m(\mathrm{A})}{m(\mathrm{A}) + m(\mathrm{B})}$	*mass fraction*	*w*	g / g
Stoffmengenanteil	$X(\mathrm{A}) = \frac{n(\mathrm{A})}{n(\mathrm{A}) + n(\mathrm{B})}$	*amount-of-substance fraction*	*x*	mol / mol
Volumenanteil	$\varphi(\mathrm{A}) = \frac{V(\mathrm{A})}{V(\mathrm{A}) + V(\mathrm{B})}$	*volume fraction*	*ϕ*	l / l
Massenkonzentration	$\beta(\mathrm{A}) = \frac{m(\mathrm{A})}{V(\mathrm{Gemisch})}$	*mass concentration*	*β* *ρ**	g / l
(Stoffmengen-) Konzentration	$c(\mathrm{A}) = \frac{n(\mathrm{A})}{V(\mathrm{Gemisch})}$	*(amount-of-substance) concentration*	*c*	mol / l
Volumenkonzentration	$\sigma(\mathrm{A}) = \frac{V(\mathrm{A})}{V(\mathrm{Gemisch})}$	*volume concentration*	*σ*	l / l
Massenverhältnis	$\zeta(\mathrm{A}) = \frac{m(\mathrm{A})}{m(\mathrm{B})}$	*mass ratio*	*ζ*	g / g
Stoffmengenverhältnis	$R(\mathrm{A}) = \frac{n(\mathrm{A})}{n(\mathrm{B})}$	*amount(-of-substance) ratio*	*R* *r*	mol / mol
Volumenverhältnis	$\psi(\mathrm{A}) = \frac{V(\mathrm{A})}{V(\mathrm{B})}$	*volume ratio*	*ψ*	l / l
Molalität	$b(\mathrm{A}) = \frac{n(\mathrm{A})}{m(\mathrm{B})}$	*molality*	*b*	mol / kg
Stoffmenge pro Masse des Gemisches 10)	$?(\mathrm{A}) = \frac{n(\mathrm{A})}{m(\mathrm{Gemisch})}$		Nach DIN unbenannte Gehaltsgröße. Symbol nicht vereinbart 10)	mmol /g

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EXAMPLE 4.7

Calculate the mole fraction of sucrose ($C_{12}H_{22}O_{11}$) in a solution made by dissolving 5.00 g sucrose in 100.0 g water.

Approach to the solution:

EXAMPLE 4.8

Calculate the amount of NaOH in a volume of 25.00 ml of a NaOH(aq) solution with c = 0.150 mol/L ?

Approach to the solution:

EXAMPLE 4.9

In addition to iron, 100 g of a CrNi 18-8 steel alloy contains 0.346 mol chromium and 0.137 mol nickel. Calculate the mass fraction of chromium and nickel in this alloy.

Approach to the solution:

EXAMPLE 4.10

What is the molar concentration of K^+ in a potassium sulfate solution that has a mass fraction $w(K_2SO_4)$ of 0.030? Density of the solution ρ = 1.06 g/mL

Approach to the solution:

DILUTIONS

- With dilutions, the concentration of the solution changes, but the amount of the dissolved substance contained in it remains the same!

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And given $c = n/V \Rightarrow n = c \times V$, the following applies to dilutions:

$$\boldsymbol{c(\mathrm{a})_1 \times V_1 = c(\mathrm{a})_2 \times V_2}$$

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EXAMPLE 4.11

How much water do you need to add to 100 mL of a H_2SO_4 solution with β = 0.05 g/mL to get a solution that has c = 0.050 mol/L?

Approach to the solution:

EXAMPLE 4.12

How much water do you have to remove from 100 mL of a NaCl solution with c = 0.100 mol/L to get a solution that has c = 0.150 mol/L?

Approach to the solution:

Activity

Activity

- Die Aktivität eines Stoffes ist eine thermodynamische Größe zur Beschreibung realer Mischungen.
- The activity of a substance describes its **"effective concentration"**, i.e. which part of the particles is effective, and takes mutual interactions into account.
  (e.g. Coulombic interactions, hydrogen bonding, Van der Waals forces…)
- All analytical measurements give the activity and not the analytical concentration. (e.g. conductivity; glass electrode;)
- The activity of a pure substance in the standard state is 1.

Activity

1. Obtain a dimensionless quantity by referring to a standard quantity

2. Consideration of mutual interactions

Activity (gases)

For gases:

1. Dimensionlessness :

The gas pressure is related to the standard condition (1.013 bar, formerly 1 atm):

$$f = p/p^0 = p/1.013\ bar$$

(applies when there are no interactions – ideal gas)

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   $$f = p/p^0 = p/1.013\ bar$$
   (applies when there are no interactions – ideal gas)

2. **Consideration of interactions**
   (real gas)
   $$f = \phi * (p/p^0);$$
   where ϕ = fugacity coefficient that takes into account the corresponding interactions

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Activity (solutions)

<u>For solutions:</u>

1. **Dimensionlessness:**
   The standard state is a solution with a concentration (*c*) of *c*° (pronounced: "C-Standard") = 1 mol/L (assuming ideal behaviour = no interactions).

$a = c/c^0 = c/(1mol/L)$

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Activity (solutions)

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The standard state is a solution with a concentration (*c*) of *c*° (pronounced: "C-Standard") = 1 mol/L (assuming ideal behaviour = no interactions).

$a = c/c^0 = c/(1mol/L)$

2. Consideration of interactions
(real solutions)

$a = \gamma \times (c/c^0);$

where γ = activity coefficient that takes into account the corresponding interactions

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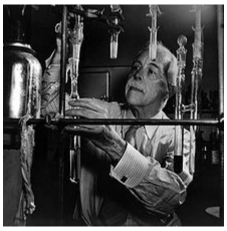
Activity (electrolyte solutions)

- The activity of solids (e.g. in solution reactions (undissolved solute)) is equal to 1.
- From a concentration of 0.00001 mol/L, the interactions disappear (from a concentration of < 0.001 mol/L, the concentration can be used as a very good approximation)

Activity coefficien γ was introduced as a purely empirical value for strong electrolytes



Gilbert Newton Lewis 1875 - 1946

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Activity (Solutions)

For γ it holds:

- γ is a dimensionless constant or has already implemented the factor $1/c^0$ and therefore has the dimension [L/mol].
- γ corrects deviations from ideal behavior.
- γ is between 0 and 1. (can also be >1 in the case of very high electrolyte concentrations)
- γ depends on the ion concentration and the ion charge of all ions present in the solution :

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Activity (Solutions)

For γ it holds:

- the smaller the γ, the greater the total concentration of ions in the solution and the greater the ionic charge of the substance under consideration.
- γ depends on the so-called **ionic strength** of a solution
- The ionic strength *I* of a solution is a measure of the electric field strength due to dissolved ions.

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