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CONCEPT: SI UNITS

The International System of Units (SI) provides 9 units of measurement as the foundation from which all other SI units can be derived.

SI Base Units

Physical Quantity	SI Base Unit Name	SI Base Unit Symbol	Description
Mass	kilogram	kg	Equal to the mass of a Pt-Ir alloy prototype constructed in 1885.
Length	meter	m	Distance light travels in a vacuum during 3.335 x 10^{-9} of a second.
Time	second	s	Related to an atomic transition of Cesium-133.
Temperature	kelvin	K	Defined as the triple point of H_2O as 273.15 K and absolute zero as 0 K.
Amount of substance	mole	mol	Number of particles equal to the number of atoms in 0.012 kg of Carbon-12 (~ 6.022 x 10^{23}).
Electrical Current	ampere	A	A unit of electric current that represents the flow of one coulmob per second.
luminous intensity	candela	cd	Measurement of luminous intensity preceptible by the human eye.
Plane angle	radian	rad	A circle contains 2 π radians.
Solid angle	steradian	sr	A sphere contains 4 π steradians.

SI Derived Units

Physical Quantity	Name	Symbol	SI Derived Units	SI Base Units
Frequency	hertz	Hz	– – –	$\frac{1}{s}$
Force	newton	N	– – –	$\frac{m \cdot kg}{s^2}$
Pressure	pascal	Pa	$\frac{N}{m^2}$	$\frac{kg}{m \cdot s^2}$
Energy, work, quantity of heat	joule	J	$N \cdot m$	$\frac{m^2 \cdot kg}{s^2}$
Power	watt	W	$\frac{J}{s}$	$\frac{m^2 \cdot kg}{s^3}$
Electrical Charge	coulomb	C	– – –	$s \cdot A$
Potential	volt	V	$\frac{W}{A}$	$\frac{m^2 \cdot kg}{s^3 \cdot A}$
Resistance	ohm	Ω	$\frac{V}{A}$	$\frac{m^2 \cdot kg}{s^3 \cdot A^2}$
Capacitance	farad	F	$\frac{C}{V}$	$\frac{s^4 \cdot A^2}{m^2 \cdot kg}$

CONCEPT: METRIC PREFIXES

Generally, we use scientific notation to turn small or large, inconvenient numbers into manageable ones, but in analytical chemistry it will become more useful to use metric prefixes.

- **Metric Prefixes** serve as labels for common base units.

10^{-24}	10^{-21}	10^{-18}	10^{-15}	10^{-12}	10^{-9}	10^{-6}	10^{-3}	10^{-2}	10^{-1}	10^{0}	10^{1}	10^{2}	10^{3}	10^{6}	10^{9}	10^{12}	10^{15}	10^{18}	10^{21}	10^{24}
yocto	zepto	atto	femto	pico	nano	micro	milli	centi	deci	0	deca	hecto	kilo	mega	giga	tera	peta	exa	zetta	yotta
(y)	(z)	(a)	(f)	(p)	(n)	(μ)	(m)	(c)	(d)		(da)	(h)	(k)	(M)	(G)	(T)	(P)	(E)	(Z)	(Y)

EXAMPLE: It is safe to assume that all dilute aqueous solutions have a density near $1.00\ \frac{g}{mL}$. If a solution is 2.50 ppt express the concentration in the following units.

$$\frac{pg}{dL}$$

PRACTICE: Based on the above example convert 5.71 ppb into the units presented below.

$$\frac{kg}{\mu L}$$

CONCEPT: MOLARITY & MOLALITY

The properties of solutions depend not only on the nature of the dissolved solutes in the solvent, but also on their concentrations. In order to express their concentrations chemists tend to use molarity (M) and molality (m).

$$M = \frac{\text{moles of solute}}{\text{Liters of Solution}} \qquad m = \frac{\text{moles of solute}}{\text{kg of solvent}}$$

EXAMPLE 1: A solution is prepared by mixing 20.00 g of $CdCl_2$ (MW of $CdCl_2$ is 183.317 g/mol) with 80.00 g of water has a density at 20 ^{o}C of 1.1988 g cm^{-3}. Compute the molarity of $CdCl_2$ in this solution.

EXAMPLE 2: In order to sterilize our drinking water, chlorine is routinely added to our water supply. If the water fountains at a park have a chlorine level of 185 ppm calculate the molarity in μM. (MW of Cl = 35.453 g/mol)

PRACTICE: MOLARITY & MOLALITY CALCULATIONS 1

EXAMPLE 1: A solution is prepared by dissolving 41.33 g nitric acid, HNO_3, in enough water to make 100.0 mL of solution. If the density of the solution is 1.380 g/mL, what is the molality of HNO_3 in the solution? (MW of HNO_3 is 63.018 g/mol).

EXAMPLE 2: If the mole fraction of ethanol, CH_3CH_2OH, in an aqueous solution is 0.090 what is the molality and molarity? Density of the solution is 1.35 g/mL.

CONCEPT: PERCENT COMPOSITION

In addition to molarity and molality we can express the concentration of solutions in a few other ways.

$$\text{Weight Percent}\left(\frac{w}{w}\right) = \frac{\text{mass of solute}}{\text{mass of solution}} \text{ x } 100 \qquad \text{Volume Percent}\left(\frac{v}{v}\right) = \frac{\text{volume of solute}}{\text{volume of solution}} \text{ x } 100$$

$$\text{Weight / Volume Percent}\left(\frac{w}{v}\right) = \frac{\text{mass of solute, g}}{\text{volume of solution, mL}} \text{ x } 100$$

EXAMPLE 1: A solution is prepared by dissolving 18.83 g sulfuric acid, H_2SO_4, in enough water to make 250 ml of solution. If the density of the solution is 1.1094 g/mL, what is the weight % H_2SO_4 in the solution? (MW of H_2SO_4 is 98.086 g/mol).

EXAMPLE 2: When lead levels in blood exceed 0.80 ppm (parts per million) the level is considered dangerous. 0.80 ppm means that 1 million g of blood would contain 0.80 g of Pb. Given that the density of blood is 1060.0 kg/m^3, how many grams of Pb would be found in 550.00 mL of blood with a Pb level of 0.583 ppm?

PRACTICE: PERCENT COMPOSITION CALCULATIONS 1

EXAMPLE 1: A 8.13% $Al_2(SO_4)_3$ solution (MW of $Al_2(SO_4)_3$ is 342.17 g/mol) has a measured density of 1.235 g/mL. Calculate the molar concentration of sulfate ions in the solution.

EXAMPLE 2: The density of a 33.8% solution of sodium acetate, $NaC_2H_3O_2$, is 1.10 g/mL. A reaction requires 68.8 g $NaC_2H_3O_2$. What volume of the solution do you need if you want to use a 50% excess of $NaC_2H_3O_2$? (MW of $NaC_2H_3O_2$ is 82.034 g/mol).

PRACTICE: How many grams of nitric acid, HNO_3, and water are found in 53.1 g of 83.1 mass percent nitric acid?

CONCEPT: DILUTIONS

A dilution involves the addition of water to a concentrated solution. Typically, a given volume of a concentrated solution is placed in a *volumetric flask* and with water being added to a determined mark.

$$M_1V_1 = M_2V_2$$

$M_1 = M_{conc}$ = Molarity or Concentration before diltution

$V_1 = V_{conc}$ = Volume before dilution

$M_2 = M_{dil}$ = Molarity or concentration after dilution

$V_2 = V_{dil}$ = Volume after dilution

_______ is a larger concentration than _______ .

_______ is a larger volume than _______.

$V_2 = V_1$ + _____________.

EXAMPLE: How many grams of 53.1 weight % NaCl (MW of NaCl is 58.443 g/mol) should be diluted to 2.50 L to make 0.15 M NaCl?

PRACTICE: If 920 mL of water is added to 78.0 mL of a 1.28 M $HBrO_4$ solution what is the resulting molarity?

PRACTICE: DILUTIONS CALCULATIONS 1

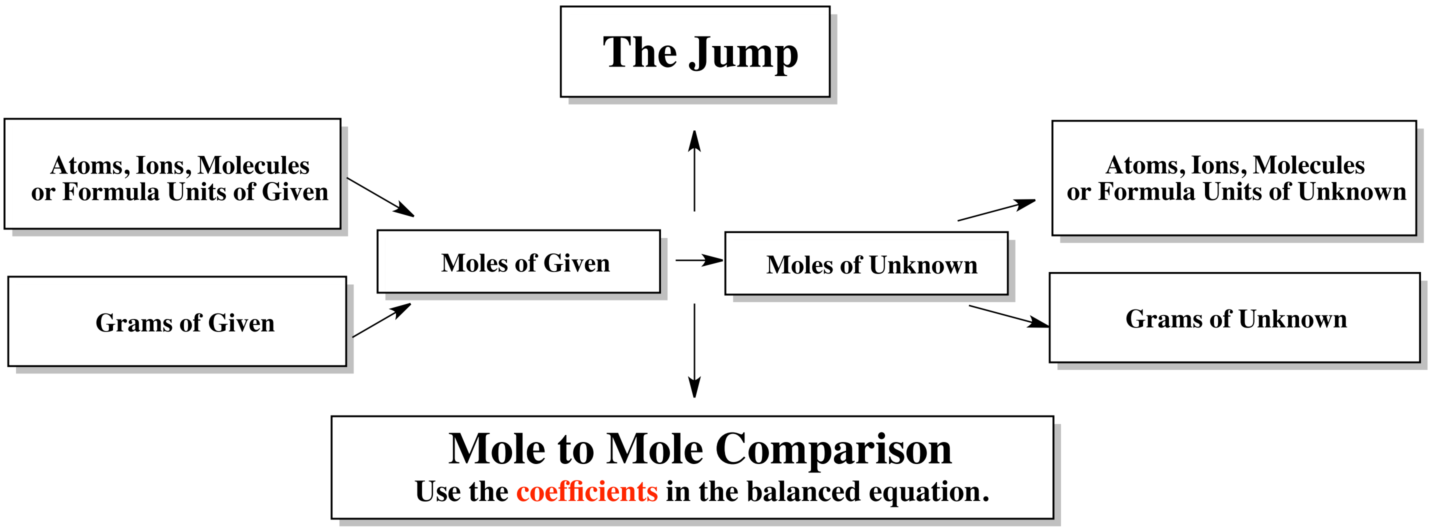
EXAMPLE 1: Calculate the density of 15.9 mL of a 49.1% by weight of aqueous perchloric acid, $HClO_4$, when it is diluted to 825 mL of 0.100 M $HClO_4$? (MW of $HClO_4$ is 100.461 g/mol)

EXAMPLE 2: The density of 63.7 wt% NaOH is 0.915 g/mL. How many milliters of water should be diluted to 850.0 mL to create 0.425 M NaOH?

CONCEPT: TITRATIONS

Gravimetric Analysis is a chemical analysis that involves determining the weight of an isolated product and *stoichiometry* is the calculations of compounds from a balanced chemical reaction.

We use this *Stoichiometric Chart* when we are given a balanced chemical equation with the known quantity of a compound or element and asked to find the unknown quantity of another compound or element.



EXAMPLE: Iron (III) can be oxidized by an acidic $K_2Cr_2O_7$ solution according to the net ionic equation below. How many microliters of a 0.250 M $FeCl_2$ are needed to completely react with 9.12 g of a compound containing 41.5% weight $K_2Cr_2O_7$?

$$Cr_2O_7^{2-} + 6\,Fe^{2+} + 14\,H^{+} \longrightarrow 2\,Cr^{3+} + 6\,Fe^{3+} + 7\,H_2O$$

CONCEPT: VOLUMETRIC TITRATIONS CALCULATIONS 1

EXAMPLE 1: Magnesium reacts with HCl according to the reaction below. How many grams of 5.310% by weight of aqueous magnesium are required to provide a 25% excess to react with 75.0 mL of 0.0550 M HCl.

$$Mg\ (s) + 2\ HCl\ (aq) \longrightarrow MgCl_2\ (aq) + H_2\ (g)$$

EXAMPLE 2: The density of 2.20 M solution of methanol (CH_3OH) is 0.976 g/mL. What is the molality of the solution? The molar mass of methanol is 31.034 g/mol.

CONCEPT: TITRATION CALCULATIONS 2

EXAMPLE 1: A 0.4317 g sample of $CaCO_3$ (MW: 100.09 g/mol) is added to flask that also contained 12.50 mL of 1.530 M HBr.

$$CaCO_3\,(aq) + 2\,HBr\,(aq) \longrightarrow CaBr_2\,(aq) + H_2O\,(l) + CO_2\,(g)$$

Additional water is then added to create a 250.0 mL of Solution A. Next 20.00 mL aliquot of solution A is taken and titrated with 0.0980 M NaOH. How many milliliters of NaOH were used?

$$NaOH\,(aq) + HBr\,(aq) \longrightarrow H_2O\,(l) + NaBr\,(aq)$$

EXAMPLE 2: A 9.2476 g sample of $M(OH)_2$ was mixed with 15.00 mL of 1.530 M HI and diluted to a final 125.0 mL of solution.

$$M(OH)_2\,(aq) + 2\,HI\,(aq) \longrightarrow 2\,H_2O\,(l) + MCl_2\,(aq)$$

A 12.00 mL aliquot of this diluted solution was taken and titrated with 18.23 mL of 0.0695 M NaOH.

$$NaOH\,(aq) + HI\,(aq) \longrightarrow H_2O\,(l) + NaCl\,(aq)$$

What is the identity of the metal representing M?

CONCEPT: TITRATION CALCULATIONS 3

EXAMPLE: A 6.2034 g sample of $Cu(OH)_n$ was mixed with 25.00 mL of 2.250 M HI and diluted to a final 250.0 mL of solution.

$$Cu(OH)_n\ (s) + n\ HI\ (aq) \longrightarrow CuI_n\ (aq) + n\ H_2O\ (l)$$

A 50.00 mL aliquot of this solution was taken and titrated with 16.25 mL of 0.1250 M KOH. What is the value of *n*?

$$KOH\ (aq) + HI\ (aq) \longrightarrow H_2O\ (l) + NaI\ (aq)$$

PRACTICE: A 1.000 g sample of Na_2CO_3 (MW: 105.99 g/mol) is dissolved in enough water to make 200.0 mL of solution. A 25.00 mL aliquot required 32.18 mL of HCl to completely neutralize it. What is the molar concentration of HCl?

$$Na_2CO_3\ (aq) + 2\ HCl\ (aq) \longrightarrow 2\ KCl\ (aq) + H_2O(l) + CO_2\ (g)$$