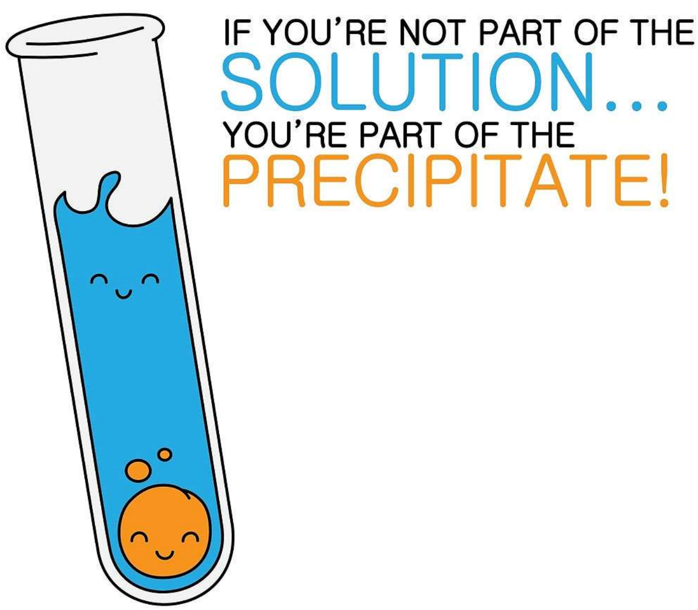
CHEMISTRY 30S

The Alchemist's Notebook

UNIT 3 – SOLUTION CHEMISTRY



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LET'S GET STARTED!

By the end of this unit, you should be able to:

- ✓ Describe the structure of water in terms of the polarity of its chemical bonds.
- ✓ Explain how ionic and covalent compounds dissolve in water using particulate representations and dissociation equations.
- ✓ Differentiate between saturated, unsaturated, and supersaturated solutions.
- ✓ Construct, from experimental data, a solubility curve of a pure substance in water and use it to solve problems.
- ✓ Explain how changes in temperature and pressure affect the solubility of solutes.
- ✓ Quantify concentration by performing various calculations including g/100mL, % concentration, ppm, and molarity.
- ✓ Prepare a solution of a known molarity from mass of solute and volume of water.
- ✓ Solve problems involving the dilution of solutions.
- ✓ Perform stoichiometric calculations on chemical reactions involving solutions using molarity.

This unit will take about **20 lessons** to complete and will make up approximately **20% of your mark**.

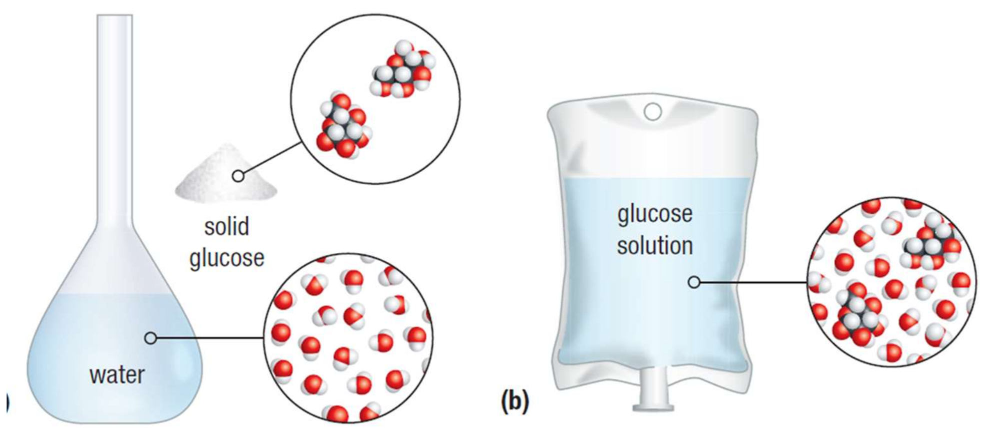
1. WHAT ARE SOLUTIONS?

CH30S UNIT 3 - SOLUTIONS WIEBE

1

WHAT ARE SOLUTIONS?

- A solution is a homogeneous mixture
- A solute is dissolved in a solvent.



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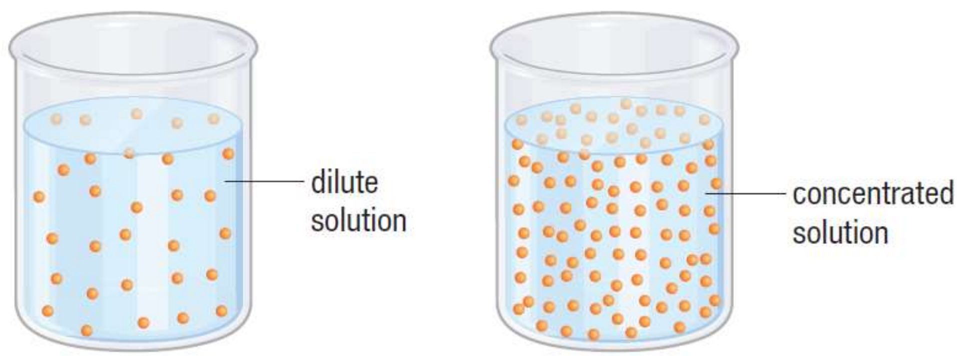
SOLUTIONS CAN HAVE VARYING SOLUTE QUANTITY.

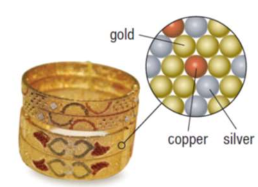
Concentration is the ratio of solute to solvent.

- **Concentrated** solutions have a high solute to solvent ratio.
- **Dilute** solutions have a low solute to solvent ratio.



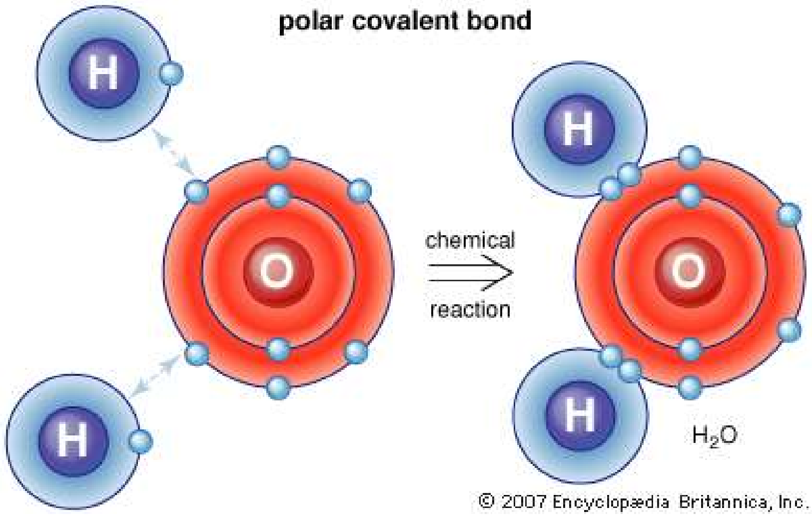
TYPES OF SOLUTIONS

Examples	Original state of solute	State of solvent
air (oxygen, argon, carbon dioxide, and other gases in nitrogen)	gas	gas
carbonated beverages (carbon dioxide and flavour compounds in water)	gas	liquid
humidity (water molecules in air)	liquid or solid	gas
alcoholic beverages (ethanol in water)	liquid	liquid
silver-coloured dental fillings (mercury amalgams)	solid	liquid
air fresheners (vapours from scented solids in air)	solid	gas
clear apple juice (flavour compounds in water)	solid	liquid
brass (an alloy of copper and zinc)	liquid	liquid



An aqueous solution has water as solvent

WATERS ROLE IN THE SOLUTION PROCESS



WATER IS A **POLAR COVALENT** MOLECULE.

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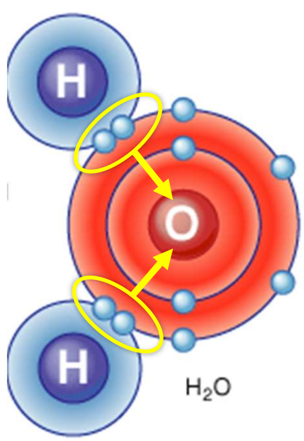
WATERS ROLE IN THE SOLUTION PROCESS



Oxygen is better at "pulling electrons" than hydrogen. As such, the shared pairs of electrons between atoms are pulled closer to the oxygen.

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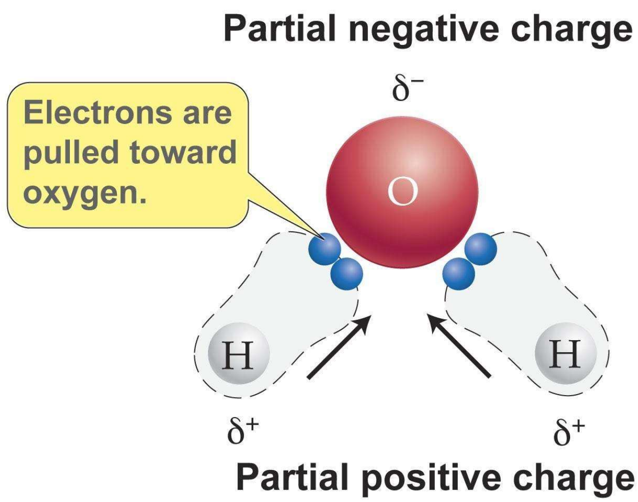
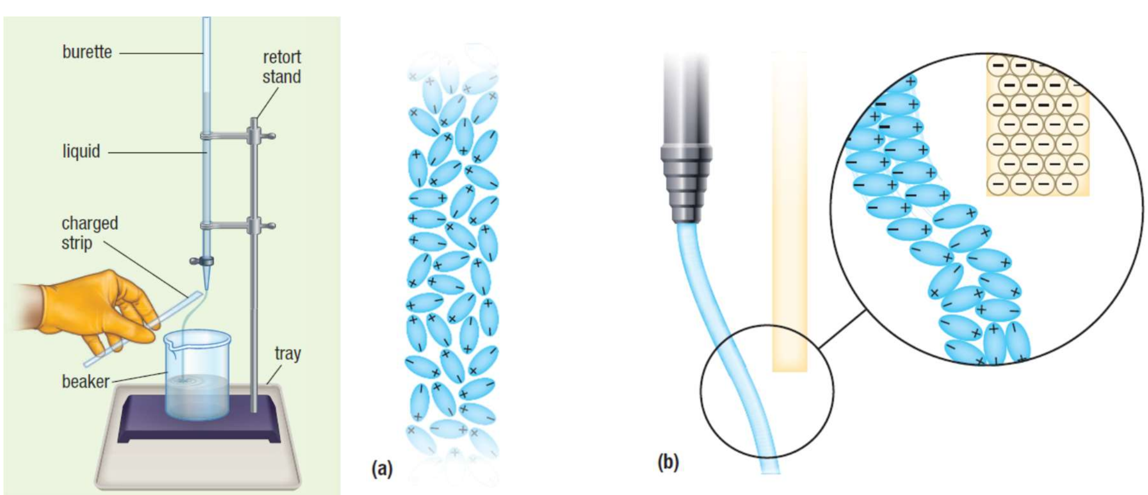
WATERS ROLE IN THE SOLUTION PROCESS

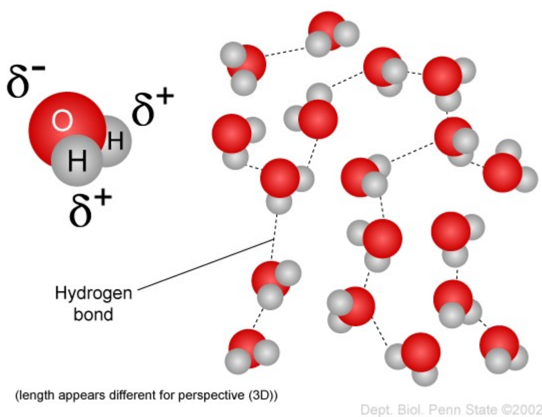


This results in slightly charged areas of the molecule called **DIPOLES**.

TESTING POLARITY OF WATER



WHEN WATER MOLECULES GET TOGETHER…



The dipoles of water molecules attract each other and **intermolecular attractions** form!

These forces explain waters high melting & boiling point, as well as it's unique density and surface tension.

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WATER WITHOUT GRAVITY

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TRY THIS…

CHALLENGE: How many drops of water can you place on top of a penny before it spills over the edges?

WHY do you think this happens?

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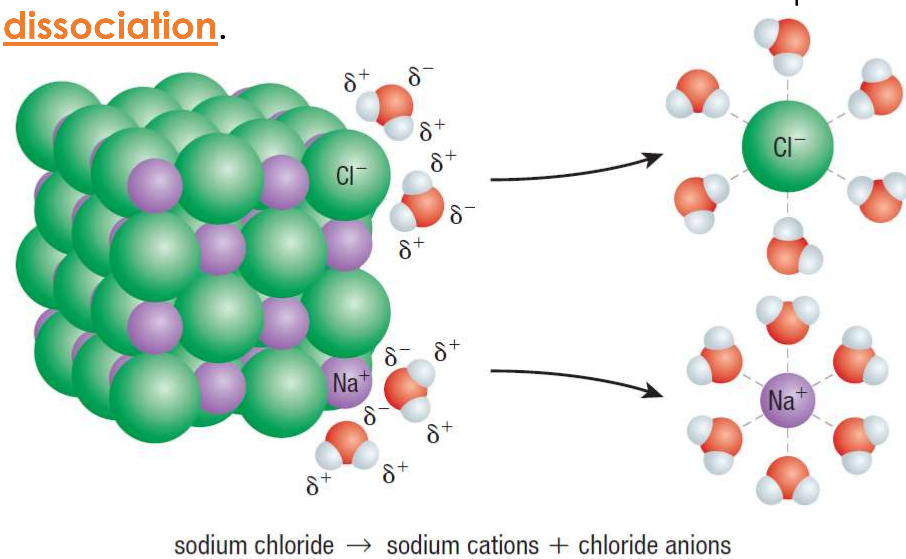
IONIC COMPOUNDS IN WATER

Ionic solutes dissolve in water as shown below. This process is called **dissociation**.



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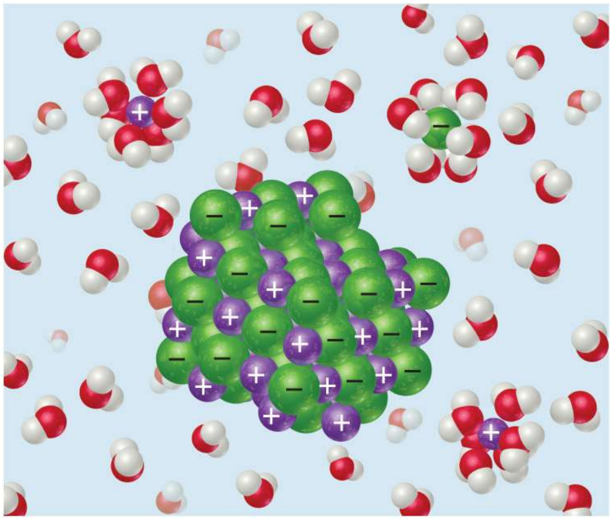
IONIC COMPOUNDS IN WATER



The positive poles of a water molecule attract to a negative ion in the crystal and removes it.

The negative pole of a water molecule attracts to a positive ion in the crystal and removes it.

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SOLUBILITY OF COMMON COMPOUNDS IN WATER

The term soluble here means > 0.1 mol/L at 25°C.

Negative Ions (Anions)	Positive Ions (Cations)	Solubility of Compounds
All	Alkali ions: Li^+, Na^+, K^+, Rb^+, Cs^+, Fr^+	Soluble
All	Hydrogen ion: H^+	Soluble
All	Ammonium ion: NH_4^+	Soluble
Nitrate, NO_3^-	All	Soluble
Chloride, Cl^- or Bromide, Br^- or Iodide, I^-	All others	Soluble
	Ag^+, Pb^{2+}, Cu^+	Low Solubility
Sulphate, SO_4^{2-}	All others	Soluble
	Ag^+, Ca^{2+}, Sr^{2+}, Ba^{2+}, Pb^{2+}	Low Solubility
Sulphide, S^{2-}	Alkali ions, H^+, NH_4^+, Be^{2+}, Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}	Soluble
	All others	Low Solubility
Hydroxide, OH^-	Alkali ions, H^+, NH_4^+, Sr^{2+}	Soluble
	All others	Low Solubility
Phosphate, PO_4^{3-} or Carbonate, CO_3^{2-} or Sulphite, SO_3^{2-}	Alkali ions, H^+, NH_4^+	Soluble
	All others	Low Solubility

Some ionic solutes dissolve better in water than others.

- <u>HIGH SOLUBILITY</u> = dissolves readily **(aq)**
- <u>LOW SOLUBILITY</u> = doesn't appear to dissolve to any extent (even though it does a bit). **(s)**

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Sulphate, SO_4^{2-}	All others	Soluble
	Ag^+, Ca^{2+}, Sr^{2+}, Ba^{2+}, Pb^{2+}	Low Solubility
Sulphide, S^{2-}	Alkali ions, H^+, NH_4^+, Be^{2+}, Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}	Soluble
	All others	Low Solubility
Hydroxide, OH^-	Alkali ions, H^+, NH_4^+, Sr^{2+}	Soluble
	All others	Low Solubility
Phosphate, PO_4^{3-} or Carbonate, CO_3^{2-} or Sulphite, SO_3^{2-}	Alkali ions, H^+, NH_4^+	Soluble
	All others	Low Solubility

Determine the general solubility of the following solutes:

sodium chloride

calcium sulphate

lithium hydroxide

zinc hydroxide

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Sample Problem 1: Writing a Dissociation Equation

Write a chemical equation for the dissociation of potassium phosphate, $K_3PO_4(s)$.

WE WRITE DISSOCIATION EQUATIONS FOR HIGHLY SOLUBLE IONIC SOLUTES ONLY!

STEP 1: Check general solubility.

STEP 2: If highly soluble, write equation. If low solubility, write "Does not dissociate to any significant extent."

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USING THE SOLUBILITY TABLE

For each of the following ionic solutes:

1. Determine if it would be highly soluble in water (aq) or low solubility in water (s).
2. Write a dissociation equation for the highly soluble solutes.

Calcium nitrate

Iron(III) chloride

Silver nitrate

Ammonium nitrite

Barium sulphate

Nickel(II) hydroxide

Aluminum sulphate

Sodium sulphide

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ANSWERS

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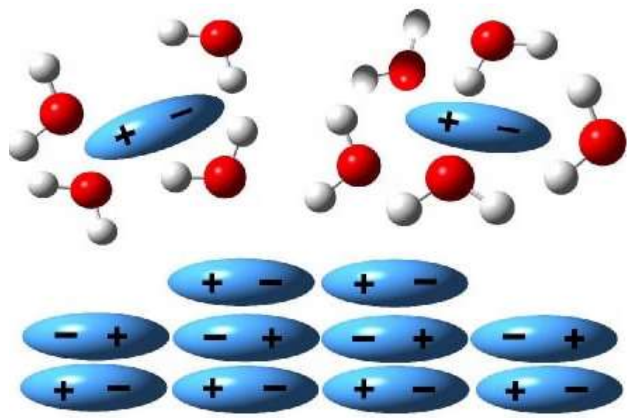
COVALENT COMPOUNDS IN WATER

- When a **polar covalent compound** dissolves in water, the polar water molecules attract to the poles of each solute molecule and pull them apart.

- Non-polar molecules DON'T DISSOLVE in water.



COVALENT COMPOUNDS IN WATER

Remember "Like Dissolves Like"

- Polar solutes dissolve in polar solvents (ie. sugar in water)

- Non-polar solutes dissolve in non-polar solvents (ie. oil in gasoline)

- All other combo's don't happen (ie. oil in water, sugar in gasoline)

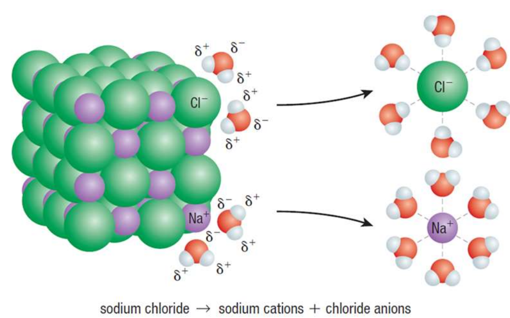
2. MEASURING SOLUBILITY

CH30S UNIT 3 - SOLUTIONS WIEBE

1

REMEMBER…

- Previously, we described the solubility of a solute as being "highly soluble" & "low solubility".
- Highly soluble compounds dissolve (dissociate) readily in water due to the polarity of the water molecules.
- The extent to which a compound dissolves in a solvent (i.e. water) is called the solubility of the solute.



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SOLUBILITY CAN BE DESCRIBED IN WORDS…

saturated solution a solution that contains the maximum quantity of solute at a given temperature and pressure

unsaturated solution a solution in which more solute can dissolve at a given temperature and pressure

supersaturated solution a solution that contains more than the maximum quantity of solute that it should at a given temperature and pressure

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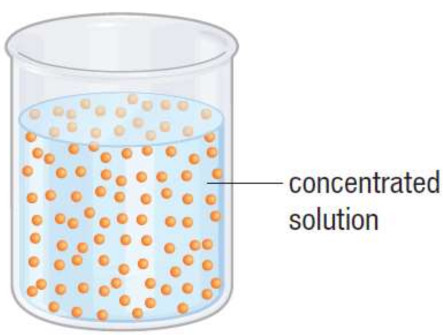
SOLUBILITY CAN BE DESCRIBED USING NUMBERS…

The solubility of a solution is expressed as the mass of solute required to form a saturated solution in 100 g of water at a given temperature.



75 circles = 75 gram solute

200 mL water

@ 25°C

$$\text{Solubility} = \frac{\text{mass of solute (g)}}{\text{volume of water (ml)}} \times 100$$

$$\text{Solubility} = \frac{75 \text{ grams}}{200 \text{ mL}} \times 100$$

Solubility = 37.5 g/100 mL H_2O

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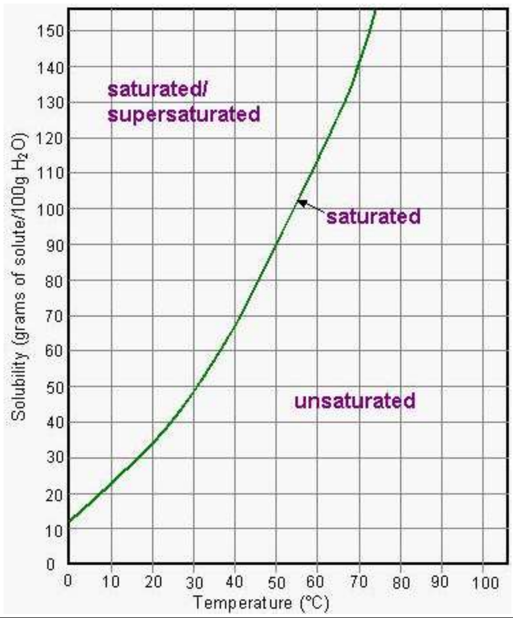
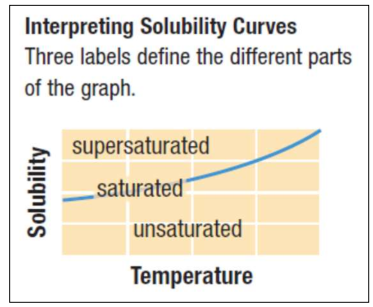
SOLUBILITY DEPENDS ON TEMPERATURE



In the lab, you learned that **solubility is affected by temperature**.



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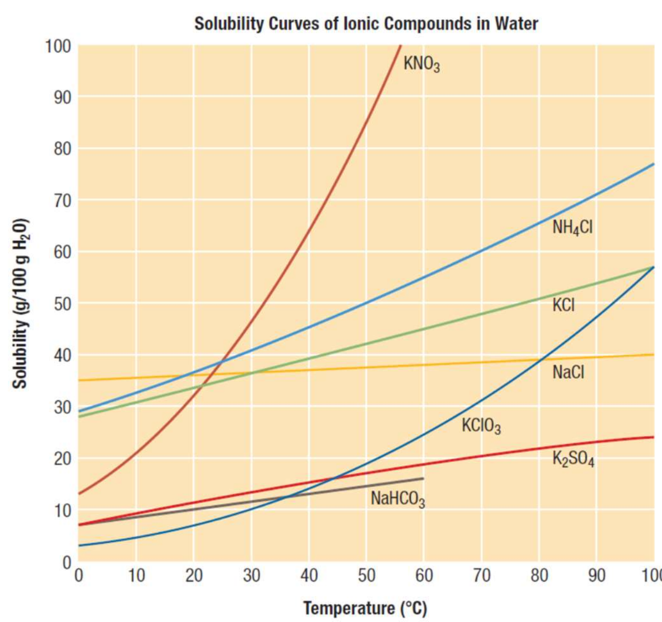
SOLUBILITY OF IONIC COMPOUNDS

The solubility of solid ionic compounds always increases with temperature.

Some solutes are affected by temperature more than others, resulting in different "curves".



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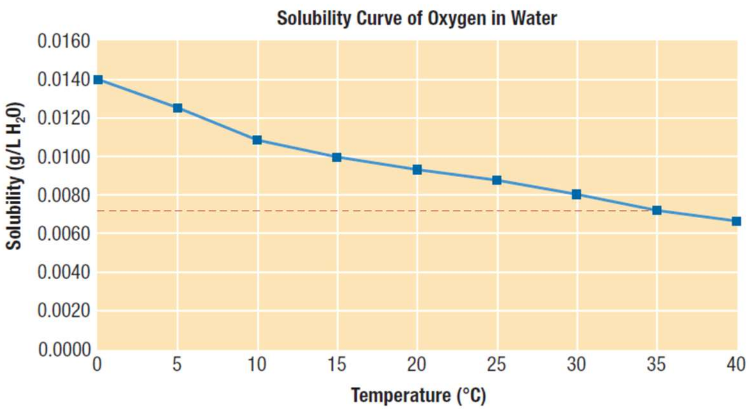
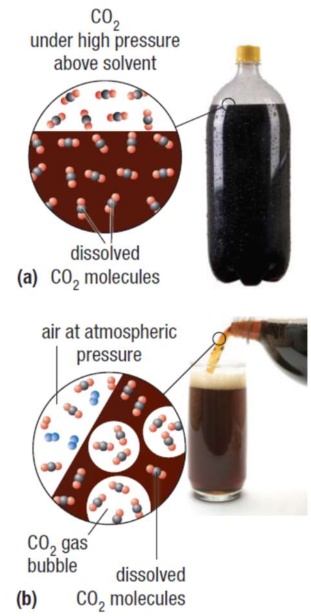
SOLUBILITY OF GASES

The solubility of gases tends to increase at low temperatures (opposite of solids) and high pressures.





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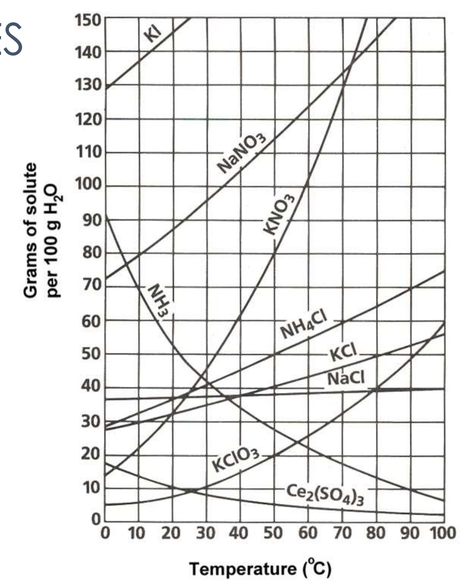
ANALYZING SOLUBILITY CURVES

What is the **solubility** of each of the following substances at the given temperature:

1. Sodium nitrate @ 10°C

2. Sodium nitrate @ 40°C



The solubility of a solution is expressed as the mass of solute required to form a saturated solution in 100 g of water at a given temperature.

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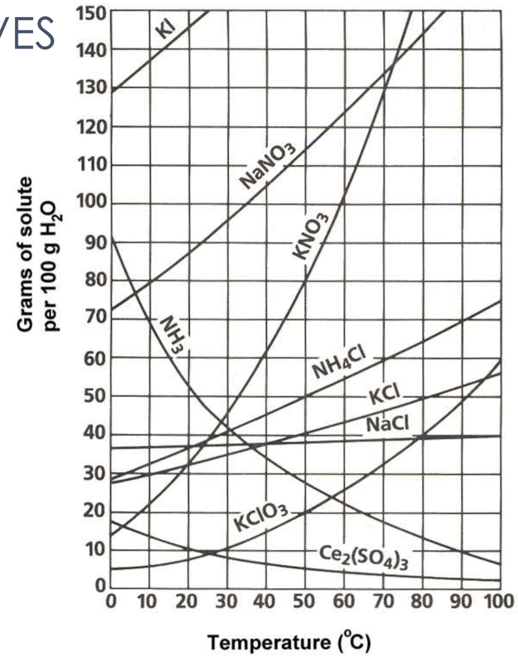
ANALYZING SOLUBILITY CURVES

3. What volume of water is needed to dissolve 35.5 g of potassium chloride at 50°C



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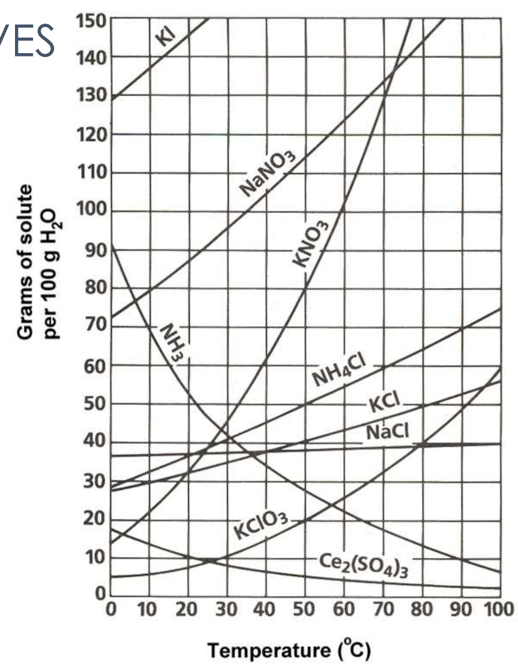
ANALYZING SOLUBILITY CURVES

4. What mass of ammonium chloride can be dissolved in 350.0 mL of water at 70°C



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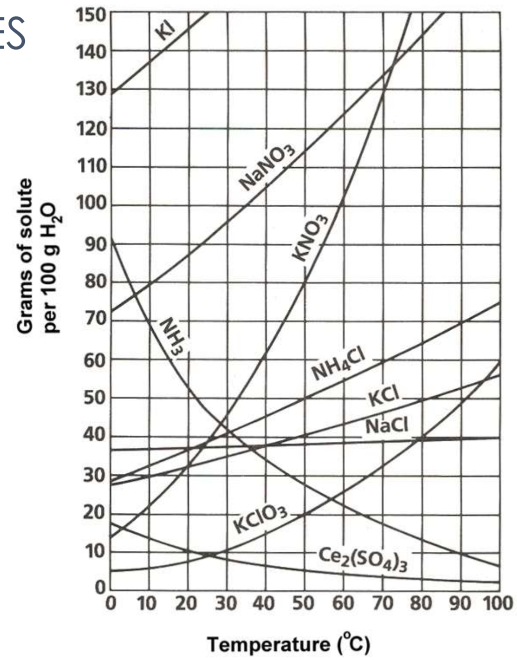
ANALYZING SOLUBILITY CURVES

Jim Bob dissolves 25.0 g $NaNO_3$ in 30.0 mL of water at 80°C.

1. What is the **concentration** of his solution in g/100 mL H_2O?

2. Explain why his solution is NOT saturated.



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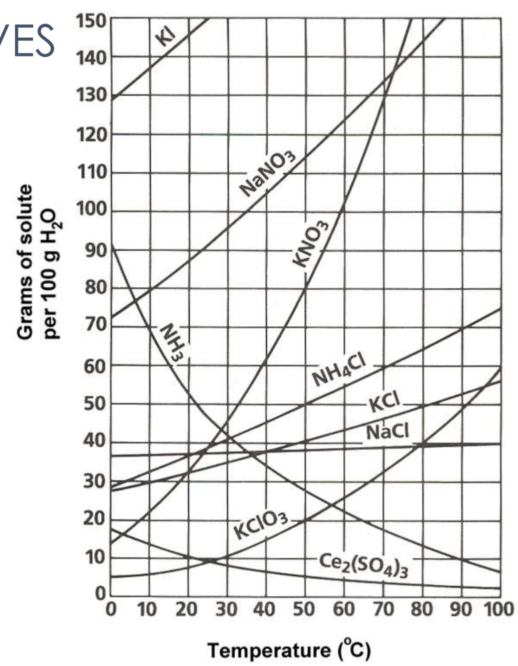
ANALYZING SOLUBILITY CURVES

Jim Bob dissolves 25.0 g $NaNO_3$ in 30.0 mL of water at 80°C.

3. What **mass of solute** could still be dissolved in his solution?



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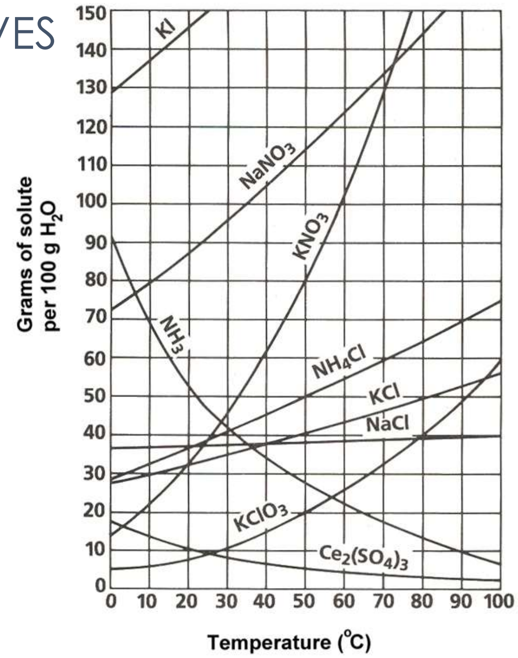
ANALYZING SOLUBILITY CURVES

Jim Bob dissolves 25.0 g $NaNO_3$ in 30.0 mL of water at 80°C.

4. What **volume of solvent** could be evaporated away to make it saturated?



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SUMMARY

- The solubility of a solution is expressed as the mass of solute required to form a saturated solution in 100 g of water at a given temperature.
- Solutions may be unsaturated, saturated, or supersaturated depending on the quantity of solute they hold at a given temperature and pressure.
- A solubility curve shows the solubility of a solute in a specific solvent over a range of temperatures.
- The solubility of solids generally increases as the temperature increases, while the solubility of gases decreases.
- The solubility of a gas increases as the applied pressure increases. Pressure has no significant effect on the solubility of solids and liquids.

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3. CONCENTRATION – CONSUMER PRODUCTS

CH30S UNIT 3 – SOLUTIONS WIEBE

1

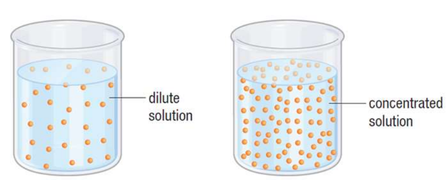
REMEMBER…

- The **concentration of a saturated solution** of a salt is called the **solubility** of that solute. Every salt has its own unique solubility at a given temperature.
- The **concentration of an unsaturated solution varies** depending on the amount of solute and solvent present.

$$\text{Concentration} = \frac{\text{quantity of solute}}{\text{quantity of solution}}$$

Quantities can be :

- **Mass (grams)**
- **Volume (millilitres)**
- **Moles (mol)**



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WHY IS CONCENTRATION IMPORTANT?

- Prescription drugs in the correct concentration make you better.
- In higher concentration they can kill you.
- In lower concentration, they aren't effective, and you could get sicker.

3

OTHER AREAS WHERE CONCENTRATION IS IMPORTANT…

- Pesticide/fertilizer use
- Food additives
- Blood alcohol content.
- Consumer products

4

CONCENTRATION IN CONSUMER PRODUCTS

v = volume (mL)   m = mass (g)

1. Percent Concentration

$$\%\frac{V}{V} = \frac{volume\ solute}{volume\ solution} \times 100$$

$$\%\frac{W}{V} = \frac{mass\ solute}{volume\ solution} \times 100$$

$$\%\frac{W}{W} = \frac{mass\ solute}{mass\ solution} \times 100$$

IF THE UNITS FOR BOTH ARE THE SAME, DON'T CONVERT!

5

CONCENTRATION IN CONSUMER PRODUCTS

2. Parts Per Million/Billion

$$ppm = \frac{quantity\ solute}{quantity\ solution} \times 10^6$$

$$ppb = \frac{quantity\ solute}{quantity\ solution} \times 10^9$$

Table 1 Parts Per Million, Billion, Trillion

Part per	Equivalent to
1 ppm	1 drop in a bathtub full of water 30 s out of a year
1 ppb	1 drop in 250 full barrels 3 s out of a century
1 ppt	1 drop in 20 Olympic-sized pools 3 s out of 100 000 years

v = volume (mL)   m = mass (g)

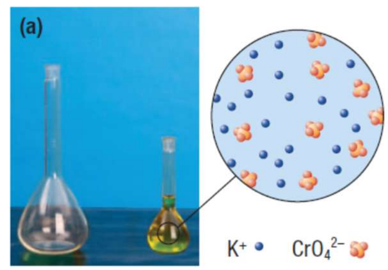
IF THE UNITS FOR BOTH ARE THE SAME, DON'T CONVERT!

6

EXAMPLE #1 – DETERMINING CONCENTRATION FROM MEASURED VALUES

0.35 g of solid potassium chromate is dissolved in enough water to make 0.50 L of solution. What is concentration of the solution expressed in:

1. percent concentration **2. ppm**



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EXAMPLE #2 – DETERMINING CONCENTRATION FROM MEASURED VALUES

A cleaning solution is created by adding 100.0 mL of Pine Sol to 4.0 L of water. What is % concentration of the solution?

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WHICH MILK IS WHICH?

Nutrition Facts
Serving Size 1 Container (150g)

Amount Per Serving	
Calories 110	Cals from Fat 15
	% Daily Value*
Total Fat 1.5g	**2%**
Saturated Fat 1g	**5%**
Trans Fat 0g	
Cholesterol 15mg	**4%**
Sodium 380mg	**16%**
Total Carbohydrate 5g	**2%**
Dietary Fiber 0g	**0%**
Sugars 4g	
Protein 19g	**38%**
Vitamin A 2% • Vitamin C 0%	
Calcium 15% • Iron 0%	

*Percent Daily Values are based on a 2,000 calorie diet.

DETERMINE THE % CONCENTRATION OF FAT IN EACH OF THE MILK LABELS.

Nutrition Facts
Valeur nutritive
Per 1 cup (250 mL) / par 1 tasse (250 mL)

Amount **Teneur**	**% Daily Value** **% valeur quotidienne**
Calories / Calories 160	
Fat / Lipides 8 g	**13** %
Saturated / saturés 5 g + Trans / trans 0.2 g	**26** %
Cholesterol / Cholestérol 30 mg	
Sodium / Sodium 110 mg	**5** %
Carbohydrate / Glucides 12 g	**4** %
Fibre / Fibres 0 g	**0** %
Sugars / Sucres 11 g	
Protein / Protéines 9 g	
Vitamin A / Vitamine A	10 %
Vitamin C / Vitamine C	0 %
Calcium / Calcium	30 %
Iron / Fer	0 %
Vitamin D / Vitamine D	45 %

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WORKING WITH % CONCENTRATIONS

The concentration of ethanol (alcohol) in a 750 mL bottle of wine is 13.5% V/V. If wine has the same density as water, calculate the volume of ethanol in the bottle.

LEARNING TIP

Working with Percentages
To determine the percentage of a number, remember that the word "of" means "multiplied by." Simply multiply the number by the percentage written as a decimal. For example,
13.5 % of 750 = (0.135)(750) = 101

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WORKING WITH % CONCENTRATIONS

Glucose ($C_6H_{12}O_6$) is used to prepare intravenous feeding solutions. What volume of 5.0% W/V glucose solution can be prepared using 125 g of glucose?

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WORKING WITH PPM/PPB CONCENTRATIONS

Swimming pool manufacturers recommend maintaining the chlorine concentration of a pool at 3.0 ppm. What mass of chlorine powder must be added to a pool containing 3.4×10^6 L of water to achieve this concentration?

LEARNING TIP

Percentages and Exponents
"ppm" is similar to the symbol "%" in the equations involving percentage concentration. You could think of the "$\times$ 100" in the above equations as "$\times 10^2$." You could even think of "%" as "pph"—parts per hundred!

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WORKING WITH PPM/PPB CONCENTRATIONS

Health Canada guidelines state that the maximum concentration of mercury that is acceptable in drinking water is 1 ppb. What volume of water would be required to have 5.0 g of Hg dissolved in it and still be acceptable?

LEARNING TIP

Percentages and Exponents
"ppm" is similar to the symbol "%" in the equations involving percentage concentration. You could think of the "× 100" in the above equations as "$\times 10^2$." You could even think of "%" as "pph"—parts per hundred!

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SUMMARY

Table 2 Measure of Concentration

Name	Abbreviation	Equation	Application
percentage volume/volume	% V/V	$c_{V/V} = \frac{V_{solute}}{V_{solution}} \times 100\ \%$	liquid–liquid mixtures
percentage weight/volume	% W/V	$c_{W/V} = \frac{m_{solute}}{V_{solution}} \times 100\ \%$	solid–liquid mixtures
percentage weight/weight	% W/W	$c_{W/W} = \frac{m_{solute}}{m_{solution}} \times 100\ \%$	solid–liquid or solid–solid mixtures
parts per million	ppm	$c_{ppm} = \frac{m_{solute}}{m_{solution}} \times 10^6\ ppm$	to express small concentrations (e.g., composition of air)
parts per billion	ppb	$c_{ppb} = \frac{m_{solute}}{m_{solution}} \times 10^9\ ppb$	to express very small concentrations (e.g., metal contaminants in water)
parts per trillion	ppt	$c_{ppt} = \frac{m_{solute}}{m_{solution}} \times 10^{12}\ ppt$	to express extremely small concentrations (e.g., traces of medications in water)

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4. CONCENTRATION – CHEMISTRY LAB WORK

CH30S UNIT 3 – SOLUTIONS WIEBE

1

UNDERSTANDING CONCENTRATION

- As the quantity of solute increases, the concentration of the solution increases and vice versa.
- As the quantity of solvent increases, the concentration decreases and vice versa.
- Spilling your solution does not change the concentration (you are losing solute and solvent at the same time!)
- As the solution evaporates, the concentration of solution increases (only solvent evaporates, not solute)

$$Conc = \frac{solute}{solution}$$

2

MOLARITY

The number of **moles** of the chemical solute per **litre of solution**.

mol/L = M

For example:

1.8 M HCl means 1.8 moles of HCl per litre of solution.

Table 1 Amount Concentrations of Common Stock Acid Solutions

Stock acid	Amount concentration (mol/L)
hydrochloric acid, $HCl(aq)$	12
nitric acid, $HNO_3(aq)$	16
sulfuric acid, $H_2SO_4(aq)$	18

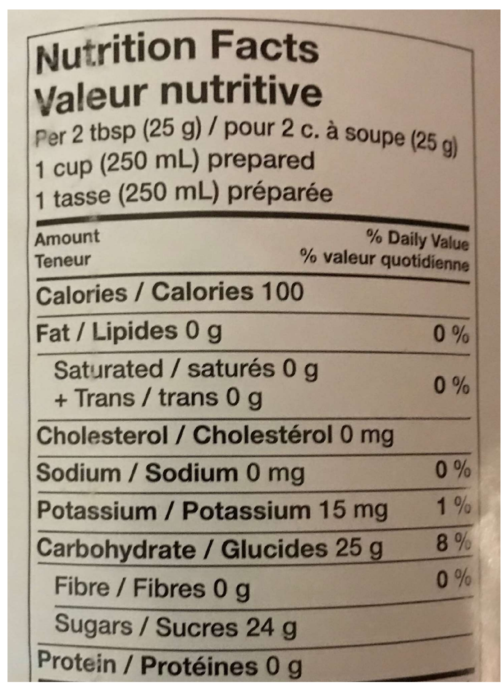
$$\text{Molarity} = \frac{\text{moles of solute}}{\text{volume of solution in liters}}$$

3

CALCULATING MOLARITY

A student makes some iced tea as per the instructions on the container. Calculate the molarity of **sugar** in the juice. (Assume the sugar in powdered drinks is all **sucrose** $C_{12}H_{22}O_{11}$

$$\text{Molarity} = \frac{\text{moles of solute}}{\text{volume of solution in liters}}$$



4

WORKING WITH MOLARITY

Household chlorine bleach is a 0.067 M solution of sodium hypochlorite. What mass of NaClO solute is required to prepare 225 mL of bleach solution?

5

PREPARING A SOLUTIONS

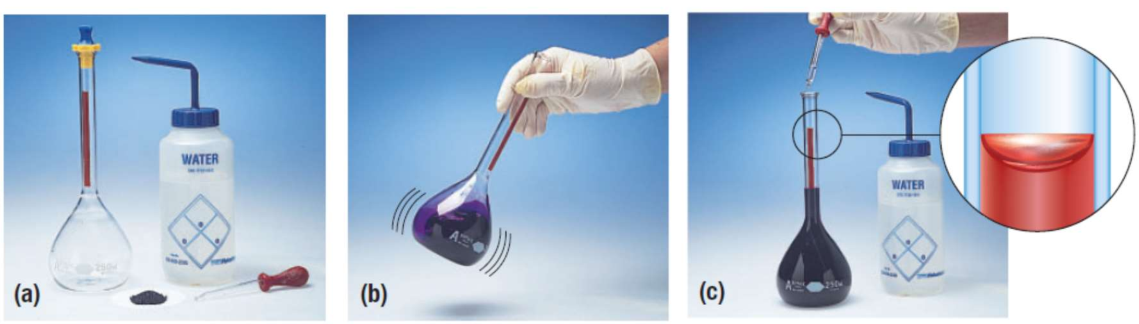


Figure 5 (a) To prepare a 250 mL sample of potassium permanganate solution, you will need a volumetric flask, distilled water, a dropper, and the required mass of potassium permanganate, $KMnO_4$. (b) First dissolve the solid $KMnO_4$ in about 100 mL of distilled water. (c) Use a dropper to add distilled water until the bottom of the meniscus lines up with the calibration mark on the flask.

6

SUMMARY

- The concentration of a solution is the quantity of dissolved solute per unit volume of solution.
- Amount concentration is the amount (in moles) of solute dissolved per litre of solution. The units of amount concentration are mol/L.
- Amount concentration is determined using the equation $c = \frac{n}{V}$.
- "Amount concentration" is the preferred IUPAC term for solution concentration (replacing molar concentration and molarity).
- Samples taken from a stock solution are diluted to prepare solutions for use in the laboratory.
- A solution of known concentration is called a standard solution.

7

5. DILUTIONS

CH30S UNIT 3 - SOLUTIONS WIEBE

1

WHAT IS A DILUTION?

Concentrated solutions have a relatively **high** molarity.

Dilute solutions have a relatively **low** molarity.

It is often **faster** to prepare a standard solutions by **diluting** a more concentrated solution.

The following **equation** can be used to solve **dilution problems** – when **water** is **added** or **removed** from a solution.

$$M_1V_1 = M_2V_2$$

M_1 = the initial molarity M_2 = the final molarity

V_1 = the initial volume V_2 = the final volume

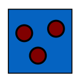
2

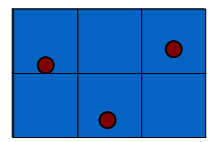
The Dilution Formula – How it Works

If we have 1 L of 3 M HCl, what is the new concentration if we dilute the acid to 6 L by adding 5 L of water?

$$1 \text{ L} \times \frac{3 \text{ mol}}{1 \text{ L}} = 3 \text{ mol HCl} \qquad \frac{3 \text{ mol HCl}}{\textbf{6 L}} = 0.5 \text{ M}$$

$$M_1v_1 = 3 \text{ mol} \qquad M_2v_2 = 3 \text{ mol}$$





Dilutions spread the same quantity of solute over a larger volume of solution!

3

A Practical Dilution…

Every can of Minute Made concentrated frozen orange juice has a volume of 250 mL and a molarity of 1.17 M $C_{12}H_{22}O_{11}$. To prepare a jug of juice, 3 cans of water are added to one can of frozen juice.

DETERMINE THE MOLARITY OF SUCROSE IN A PREPARED JUG OF OJ.

4

DETERMINE THE MOLARITY OF SUCROSE IN A PREPARED JUG OF OJ.

5

EXAMPLE #1

What volume of 0.755 M sodium chloride solution is required to prepare 250.0 mL of a 0.500 M solution?

6

EXAMPLE #2

A student measures 100.0 mL of a 5.0 M potassium chloride solution and adds enough water to it to make the volume 2.0 L. What will be the molarity of this new solution?

7

EXAMPLE #3

How much water would you need to add to 200.0 mL of a 1.50 M sodium nitrate solution to dilute it down to 0.250 M?

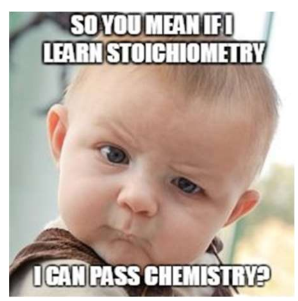
8

6. STOICHIOMETRY OF SOLUTIONS

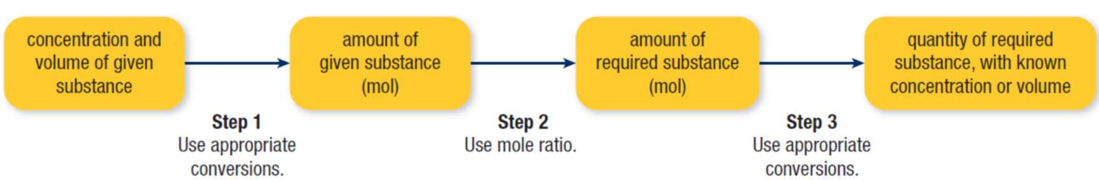
CH30S UNIT 2 - SOLUTIONS WIEBE

1

GENERAL STOICH PRINCIPLES



Solving stoichiometry problems involves the same general strategy, regardless of the substances involved.



2

molar mass of x → grams (x) ↔ moles (x)

molar mass of y → moles (y) ↔ grams (y)

grams (x) ↔ moles (x) ↔ moles (y) ↔ grams (y)

mole ratio from balanced equation → moles (x) ↔ moles (y)

22.4L/mol → volume (x) ↔ moles (x)

22.4L/mol → moles (y) ↔ volume (y)

volume (x) ↔ moles (x) ↔ moles (y) ↔ volume (y)

mole ratio from balanced equation → moles (x) ↔ moles (y)

Molarity of x → volume (x) ↔ moles (x)

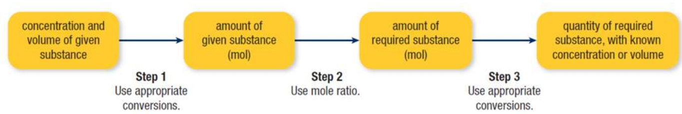
Molarity of y → moles (y) ↔ volume (y)

volume (x) ↔ moles (x) ↔ moles (y) ↔ volume (y)

mole ratio from balanced equation → moles (x) ↔ moles (y)

3

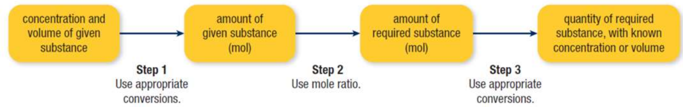
EXAMPLE #1



Determine the minimum volume of 0.42 mol/L sodium sulfate, $Na_2SO_4(aq)$, that is required to react completely with all the barium ions in 500.0 mL of a 0.100 mol/L barium chloride, $BaCl_2$, solution.

4

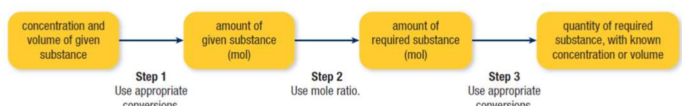
EXAMPLE #2



Determine the mass of silver that could be produced when 50.0 mL of 0.200 M silver nitrate reacts fully with an excess amount of copper.

5

EXAMPLE #3



Predict the mass of precipitate expected when 1.50 L of 0.800 mol/L sodium carbonate, Na_2CO_3, is mixed with 850 mL of a 1.00 mol/L aluminum nitrate, $Al(NO_3)_3$, solution.

6

SOLUBILITY OF COMMON COMPOUNDS IN WATER

The term soluble here means > 0.1 mol/L at 25°C.

Negative Ions (Anions)	Positive Ions (Cations)	Solubility of Compounds
All	Alkali ions: Li^+, Na^+, K^+, Rb^+, Cs^+, Fr^+	Soluble
All	Hydrogen ion: H^+	Soluble
All	Ammonium ion: NH_4^+	Soluble
Nitrate, NO_3^-	All	Soluble
Chloride, Cl^- or Bromide, Br^- or Iodide, I^-	All others	Soluble
	Ag^+, Pb^{2+}, Cu^+	Low Solubility
Sulphate, SO_4^{2-}	All others	Soluble
	Ag^+, Ca^{2+}, Sr^{2+}, Ba^{2+}, Pb^{2+}	Low Solubility
Sulphide, S^{2-}	Alkali ions, H^+, NH_4^+, Be^{2+}, Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}	Soluble
	All others	Low Solubility
Hydroxide, OH^-	Alkali ions, H^+, NH_4^+, Sr^{2+}	Soluble
	All others	Low Solubility
Phosphate, PO_4^{3-} or Carbonate, CO_3^{2-} or Sulphite, SO_3^{2-}	Alkali ions, H^+, NH_4^+	Soluble
	All others	Low Solubility

Periodic Chart of Ions

Table of Polyatomic Ions

acetate	CH_3COO^-	dichromate	$Cr_2O_7^{2-}$	dihydrogen phosphate	$H_2PO_4^-$
ammonium	NH_4^+	cyanide	CN^-	silicate	SiO_3^{2-}
benzoate	$C_6H_5COO^-$	hydroxide	OH^-	sulphate	SO_4^{2-}
borate	BO_3^{3-}	iodate	IO_3^-	sulphite	SO_3^{2-}
carbonate	CO_3^{2-}	nitrate	NO_3^-	hydrogen sulphide	HS^-
hydrogen carbonate	HCO_3^-	nitrite	NO_2^-	hydrogen sulphate	HSO_4^-
chlorate	ClO_3^-	oxalate	$OOCCOO^{2-}$	hydrogen sulphite	HSO_3^-
hypochlorite	ClO^-	permanganate	MnO_4^-	thiocyanate	SCN^-
chromate	CrO_4^{2-}	phosphate	PO_4^{3-}	thiosulphate	$S_2O_3^{2-}$
		hydrogen phosphate	HPO_4^{2-}		

IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIIIB	VIIIB	VIIIB	IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA
1 H^+ hydrogen																	2 He helium
3 Li^+ lithium	4 Be^{2+} Beryllium											5 B boron	6 C carbon	7 N^{3-} nitride	8 O^{2-} oxide	9 F^- fluoride	10 Ne neon
11 Na^+ sodium	12 Mg^{2+} magnesium											13 Al^{3+} aluminum	14 Si silicon	15 P^{3-} phosphide	16 S^{2-} sulfide	17 Cl^- chloride	18 Ar argon
19 K^+ potassium	20 Ca^{2+} calcium	21 Sc^{3+} scandium	22 Ti^{4+} titanium (IV) Ti^{3+} titanium (III)	23 V^{5+} vanadium (V) V^{4+} vanadium (IV)	24 Cr^{3+} chromium (III) Cr^{2+} chromium (II)	25 Mn^{2+} manganese (II) Mn^{4+} manganese (IV)	26 Fe^{3+} iron (III) Fe^{2+} iron (II)	27 Co^{2+} cobalt (II) Co^{3+} cobalt (III)	28 Ni^{2+} nickel (II) Ni^{3+} nickel (III)	29 Cu^{2+} copper (II) Cu^+ copper (I)	30 Zn^{2+} zinc	31 Ga^{3+} gallium	32 Ge^{4+} germanium	33 As^{3-} arsenide	34 Se^{2-} selenide	35 Br^- bromide	36 Kr krypton
37 Rb^+ rubidium	38 Sr^{2+} strontium	39 Y^{3+} yttrium	40 Zr^{4+} zirconium	41 Nb^{5+} niobium (V) Nb^{3+} niobium (III)	42 Mo^{6+} molybdenum	43 Tc^{7+} technetium	44 Ru^{3+} ruthenium (III) Ru^{4+} ruthenium (IV)	45 Rh^{3+} rhodium	46 Pd^{2+} paladium (II) Pd^{4+} paladium (IV)	47 Ag^+ silver	48 Cd^{2+} cadmium	49 In^{3+} indium	50 Sn^{4+} tin (IV) Sn^{2+} tin (II)	51 Sb^{3+} antimony (III) Sb^{5+} antimony (V)	52 Te^{2-} telluride	53 I^- iodide	54 Xe xenon
55 Cs^+ cesium	56 Ba^{2+} barium	57 La^{3+} lanthanum	72 Hf^{4+} hafnium	73 Ta^{5+} tantalum	74 W^{6+} tungsten	75 Re^{7+} rhenium	76 Os^{4+} osmium	77 Ir^{4+} iridium	78 Pt^{4+} platinum (IV) Pt^{2+} platinum (II)	79 Au^{3+} gold (III) Au^+ gold (I)	80 Hg^{2+} mercury (II) Hg^+ mercury (I)	81 Tl^+ thallium (I) Tl^{3+} thallium (III)	82 Pb^{2+} lead (II) Pb^{4+} lead (IV)	83 Bi^{3+} bismuth (III) Bi^{5+} bismuth (V)	84 Po^{2+} polonium (II) Po^{4+} polonium (IV)	85 At^- astatide	86 Rn radon
87 Fr^+ francium	88 Ra^{2+} radium	89 Ac^{3+} actinium															

58 Ce^{3+} cerium	59 Pr^{3+} praseodymium	60 Nd^{3+} neodymium	61 Pm^{3+} promethium	62 Sm^{3+} samarium (III) Sm^{2+} samium(II)	63 Eu^{3+} europium (III) Eu^{2+} europium(II)	64 Gd^{3+} gadolinium	65 Tb^{3+} terbium	66 Dy^{3+} dysprosium	67 Ho^{3+} holmium	68 Er^{3+} erbium	69 Tm^{3+} thulium	70 Yb^{3+} ytterbium (III) Yb^{2+} ytterbium (II)	71 Lu lutetium
90 Th^{4+} thorium	91 Pa^{5+} protactinium (V) Pa^{4+} protactinium(IV)	92 U^{6+} uranium (VI) U^{4+} uranium (IV)	93 Np^{5+} neptunium	94 Pu^{4+} plutonium (IV) Pu^{6+} plutonium (VI)	95 Am^{3+} americium (III) Am^{4+} americium (IV)	96 Cm^{3+} curium	97 Bk^{3+} berkelium (III) Bk^{4+} berkelium (IV)	98 Cf^{3+} californium	99 Es^{3+} einsteinium	100 Fm^{3+} fermium	101 Md^{2+} mendelevium(II) Md^{3+} mendelevium (III)	102 No^{2+} nobelium (II) No^{3+} nobelium (III)	103 Gd^{3+} lawrencium

KEY

atomic number →	26
ion charge →	Fe^{3+}
stock name (IUPAC) →	iron (III)
symbol →	Fe^{2+}
	iron (II)

PERIODIC TABLE OF THE ELEMENTS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** Hydrogen 1.0																	2 **He** Helium 4.0
3 **Li** Lithium 6.9	4 **Be** Beryllium 9.0											5 **B** Boron 10.8	6 **C** Carbon 12.0	7 **N** Nitrogen 14.0	8 **O** Oxygen 16.0	9 **F** Fluorine 19.0	10 **Ne** Neon 20.2
11 **Na** Sodium 23.0	12 **Mg** Magnesium 24.3											13 **Al** Aluminum 27.0	14 **Si** Silicon 28.1	15 **P** Phosphorus 31.0	16 **S** Sulphur 32.1	17 **Cl** Chlorine 35.5	18 **Ar** Argon 39.9
19 **K** Potassium 39.1	20 **Ca** Calcium 40.1	21 **Sc** Scandium 45.0	22 **Ti** Titanium 47.9	23 **V** Vanadium 50.9	24 **Cr** Chromium 52.0	25 **Mn** Manganese 54.9	26 **Fe** Iron 55.8	27 **Co** Cobalt 58.9	28 **Ni** Nickel 58.7	29 **Cu** Copper 63.5	30 **Zn** Zinc 65.4	31 **Ga** Gallium 69.7	32 **Ge** Germanium 72.6	33 **As** Arsenic 74.9	34 **Se** Selenium 79.0	35 **Br** Bromine 79.9	36 **Kr** Krypton 83.8
37 **Rb** Rubidium 85.5	38 **Sr** Strontium 87.6	39 **Y** Yttrium 88.9	40 **Zr** Zirconium 91.2	41 **Nb** Niobium 92.9	42 **Mo** Molybdenum 95.9	43 **Tc** Technetium (98)	44 **Ru** Ruthenium 101.1	45 **Rh** Rhodium 102.9	46 **Pd** Palladium 106.4	47 **Ag** Silver 107.9	48 **Cd** Cadmium 112.4	49 **In** Indium 114.8	50 **Sn** Tin 118.7	51 **Sb** Antimony 121.8	52 **Te** Tellurium 127.6	53 **I** Iodine 126.9	54 **Xe** Xenon 131.3
55 **Cs** Cesium 132.9	56 **Ba** Barium 137.3	57 **La** Lanthanum 138.9	72 **Hf** Hafnium 178.5	73 **Ta** Tantalum 180.9	74 **W** Tungsten 183.8	75 **Re** Rhenium 186.2	76 **Os** Osmium 190.2	77 **Ir** Iridium 192.2	78 **Pt** Platinum 195.1	79 **Au** Gold 197.0	80 **Hg** Mercury 200.6	81 **Tl** Thallium 204.4	82 **Pb** Lead 207.2	83 **Bi** Bismuth 209.0	84 **Po** Polonium (209)	85 **At** Astatine (210)	86 **Rn** Radon (222)
87 **Fr** Francium (223)	88 **Ra** Radium (226)	89 **Ac** Actinium (227)	104 **Rf** Rutherfordium (261)	105 **Db** Dubnium (262)	106 **Sg** Seaborgium (263)	107 **Bh** Bohrium (262)	108 **Hs** Hassium (265)	109 **Mt** Meitnerium (266)									

Key:

14	Atomic Number
Si	Symbol
Silicon	Name
28.1	Atomic Mass

58 **Ce** Cerium 140.1	59 **Pr** Praseodymium 140.9	60 **Nd** Neodymium 144.2	61 **Pm** Promethium (145)	62 **Sm** Samarium 150.4	63 **Eu** Europium 152.0	64 **Gd** Gadolinium 157.3	65 **Tb** Terbium 158.9	66 **Dy** Dysprosium 162.5	67 **Ho** Holmium 164.9	68 **Er** Erbium 167.3	69 **Tm** Thulium 168.9	70 **Yb** Ytterbium 173.0	71 **Lu** Lutetium 175.0
90 **Th** Thorium 232.0	91 **Pa** Protactinium 231.0	92 **U** Uranium 238.0	93 **Np** Neptunium (237)	94 **Pu** Plutonium (244)	95 **Am** Americium (243)	96 **Cm** Curium (247)	97 **Bk** Berkelium (247)	98 **Cf** Californium (251)	99 **Es** Einsteinium (252)	100 **Fm** Fermium (257)	101 **Md** Mendelevium (258)	102 **No** Nobelium (259)	103 **Lr** Lawrencium (262)

Based on mass of C^{12} at 12.00.

Values in parentheses are the masses of the most stable or best known isotopes for elements which do not occur naturally.