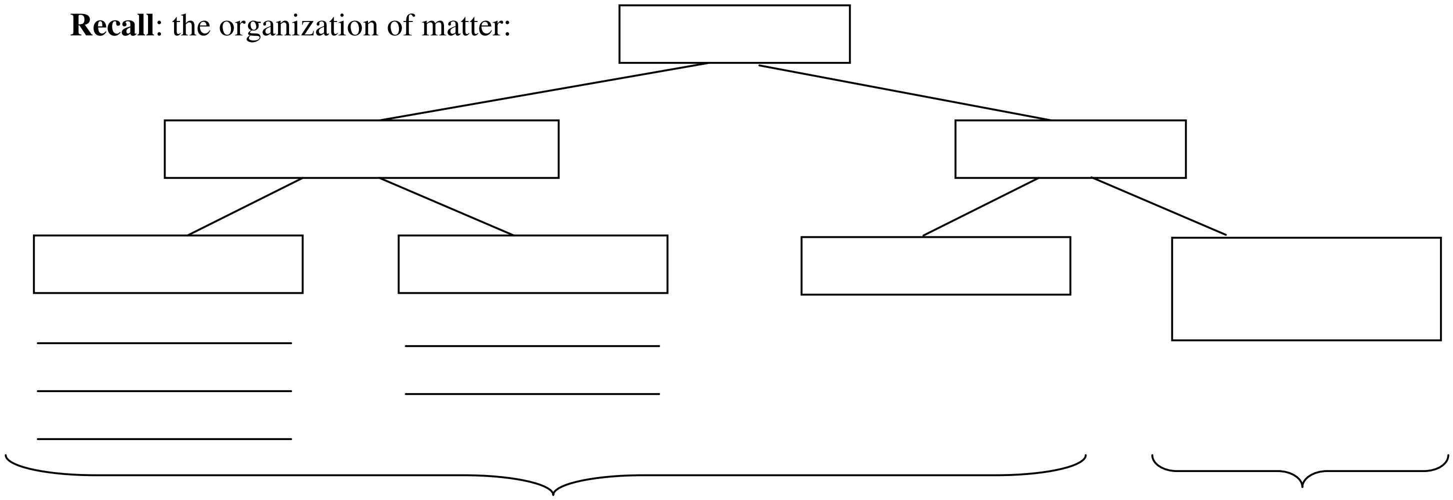
SCH 3UI Unit 9 Outline: Solutions, Acids and Bases

Lesson	Topics Covered	Homework Questions and Assignments
1	**Note: Introduction to Solutions** • review of the organization of matter • define: solution, solute, solvent • types of solutions • characteristics of solutions **Note**: **Solubility of Substances** • explaining why substances dissolve • hydration shells and dissociation	• complete worksheet: Introduction to Solutions: Practice Questions • complete the summary chart comparing the types of matter (handed out in class) • read pages 277 – 278 in text. Visualize and UNDERSTAND what is happening when an ionic substance dissolves in water
2	**Note: Describing the Concentration of Solutions Qualitatively** • concentrated vs. dilute • saturated, unsaturated and super-saturated • the seed crystal test for saturation **Note**: **Solubility Curves** • definition of solubility • solubility and temperature • reading solubility curves	• complete worksheet: Practice Problems: Solubility Curves
3	**Note: Concentration of Solutions, quantitative** • % W/W • % W/V • % V/V • density	• answer questions 1 – 3 on worksheet: Concentration of Solutions Problems
4	**Note: Concentration of Solutions, quantitative (continued)** • molar concentration (C in mol/L) • how to make solutions • diluting stock solutions	• answer questions 4 - 8 on worksheet: Concentration of Solutions Problems
5	**Note: Introduction to Acids, Bases and Neutral Substances** • definitions • properties (demo lab)	• complete handout: Properties of Acids and Bases
6	**Note: Reactions of Acids and Bases** • acids plus metals • acids plus carbonates • acids plus bases (neutralization)	• complete handout: Reactions of Acids and Bases
7	**Describing Acids and Bases** • concentration • ionization vs. dissociation • strength • pH	• complete handout: Strength, Concentration and pH of Acids and Bases
8	**Note: Preparing Solutions of Acids and Bases** • diluting acid stock solutions (AAA) • calculating the amount of solid acid or base needed to make a solution with a certain concentration	• complete Practice Questions: Concentrations of Acids and Bases

Introduction to Solutions

Recall: the organization of matter:



A **solution** is defined as a ____________________________________. Solutions contain _____________ types of particles, __________ mixed.

A solution is made of a _____________ plus one or more ______________.
The ____________ is the substance that is present in the _____________ amount.
The ____________ is the substance that is present is the _____________ amount. It is ______________.

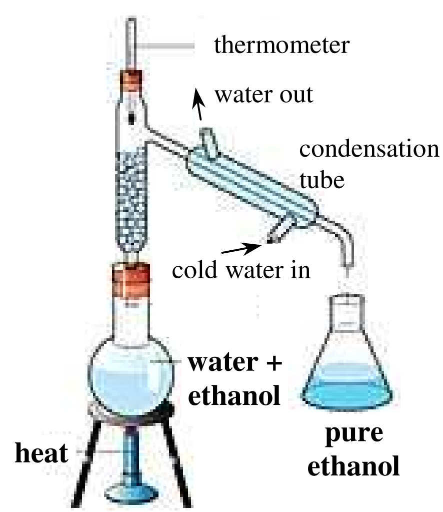
There are many different types of solutions, depending on the ___________ of the solute and solvent:

a) solid in liquid: __________________________
b) gas in liquid: ___________________________
c) gas in gas: _____________________________
d) liquid in gas: ___________________________
e) liquid in liquid: __________________________
f) solid in solid: ____________________________
g) gas in solid: _____________________________
h) liquid in solid: ____________________________

A solution in which the solvent is ___________ is known as an ______________ solution ( ).
Note: not ALL solutions are ____________________, for example __________ in __________ solutions (__________) such as_________ are ____________. All _____________ solutions are ________________.

Solutions have the following characteristics:

1. homogeneous: ______________________________________
2. made of only one _______. A phase is a ______________________ of matter, with ____________ characteristics (it all looks the same)
3. permanent: the ___________ will not _______________________
4. the solute can **NOT** be separated from the solvent by ____________
5. the solute can be separated from the solvent by _________________ or ______________________. These methods are _______________ and separate substances based on differences in their _____________ _____________.
6. solutions have ______________ composition, that is, the __________________ of solute and solvent can change
   eg. ________________ of sugar in ____________ of water
   ________________ of sugar in ____________ of water



Introduction to Solutions: Practice Questions

Read pages 264, 266-267 of Nelson Chemistry 11 and refer to your class notes (including the notes from the first unit) to answer the following questions:

1. Define the following terms:
a) matter, pure substance, mixture, element, compound, solution, mechanical mixture
b) aqueous solution, alloy
c) solvent, solute, homogeneous, heterogeneous, phase
d) electrolyte, non-electrolyte

2. Why is water known as the "universal solvent"? (page 264)

3. List six unwanted substances that are commonly dissolved in water supplies. (page 264)

4. Explain why homogenized milk is not considered to be a solution. (page 266).

5. Are all solutions transparent? Give an example to defend your answer.

6. Are all aqueous solutions transparent?

7. Are all aqueous solutions colourless?

8. What type of compounds are electrolytes? What type of compounds are non-electrolytes?

9. Identify the solute(s) and solvent in each of the following solutions:
a) sterling silver (often stamped with the number 925) is an alloy of 92.5% silver and 7.5% copper
b) tincture of iodine is 3% solid iodine dissolved in 97% ethanol (alcohol)
c) brass is 85% copper and 15% zinc
d) "regular" gasoline is a mixture of 87% octane with other hydrocarbons
e) bronze can be made by melting together 80% copper and 20% tin
f) stainless steel is a homogeneous mixture of approximately 78% iron, 15% chromium and 7% nickel
g) air is 78% nitrogen, 20.9% oxygen and 1% trace gases (Ar, Ne, CH_4, CO_2, He etc)
h) carbonated water is made by dissolving about 1.8 g of carbon dioxide in 1.0 L of water

10. Answer questions 1, 2, 4, 5 and 6 on page 269. (Note: the text uses the term "molecular" to indicate a covalent compound)

Describing the Concentration of Solutions: Qualitative

Concentration can be described, **qualitatively** (__________________________) as follows:

1. Using the words _____________ and _______________________:

- A solution that contains relatively little solute in a large amount of solvent is said to be ___________
- A solution that contains a relatively large amount of solute in a small amount of solvent is said to be ____________________

2. Concentration can also be described in terms of its _________________, or how much solute is dissolved compared to the _____________________________ of solute that can dissolve in a certain solvent at a specified ___________________

a) If a solution contains the ____________________________ of solute that will dissolve in the solvent, then the solution is said to be _________________

- a ________________ solution is made by adding solute to the solvent and stirring until no more will dissolve. There may be a few crystals of solute left on the bottom

b) If a solution contains _______________ the maximum amount of solute than will dissolve in that solvent at a certain temperature, then the solution is said to be __________________

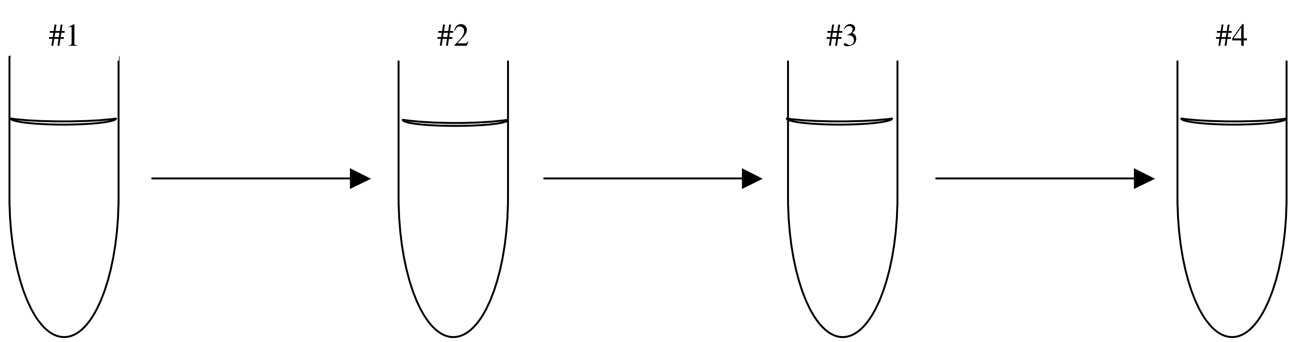
- an _________________ solution is made by adding __________ or changing the __________________
- for a solid in liquid solution, you can make the solution unsaturated by ______________ it
- for a gas in liquid solution, you can make the solution unsaturated by ______________ it. Gases dissolve better at __________ temperatures.

c) If a solution contains __________________ the maximum amount of solute than will normally dissolve in that solvent at a certain temperature, then the solution is said to be _________________________

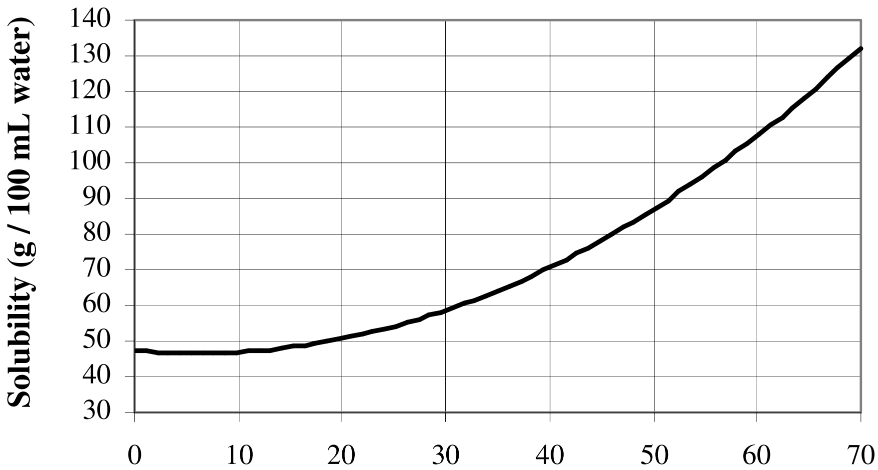
- a _______________________ solution is made by ____________ a saturated solution to dissolve the solute, and then _____________ it to a lower temperature, where solubility is ___________. As long as there are no ____________ present or ______________________, the extra solute will stay in solution and the solution will be ___________________________

To test if a solution is saturated, unsaturated or super-saturated, add a single ____________________

- If the solution is unsaturated, the seed crystal will _______________
- If the solution is saturated, the seed crystal will ___________________. It will just ______________ ____________________
- If the solution is super-saturated, the seed crystal will cause other crystals of the solute to _________________________ of the solution, leaving a ______________ solution behind



The Solubility of Potassium Nitrate



Solubility is defined as the maximum amount of a solute that will dissolve in a certain amount of solution at a specified temperature.

Solubility curves show how solubility changes with temperature.

1. Label the regions of the solubility curve where the solution is saturated, unsaturated and super-saturated.

2. Use the graph to estimate the solubility of potassium nitrate in 100 mL of water at:

a) 10 °C __________________ c) 20 °C __________________

b) 55 °C __________________ d) 65 °C __________________

3. Use the graph to estimate how many grams of potassium nitrate will dissolve in 300 mL of water at:

a) 5 °C ________________ c) 15 °C __________________

b) 50 °C ________________ d) 70 °C __________________

4. What minimum temperature is required to dissolve:

a) 48 g of KNO_3 in 100 mL of water ______ c) 82 g of KNO_3 in 100 mL of water ______

b) 35 g of KNO_3 in 50 mL of water ______ d) 20 g of KNO_3 in 25 mL of water ______

5. Are the following solutions saturated, unsaturated or supersaturated at the temperatures given below?

a) 100 g of KNO_3 in 100 mL of water at 60°C __________

b) 100 g of KNO_3 in 100 mL of water at 40°C __________

c) 40 g of KNO_3 in 25 mL of water at 70°C __________

d) 200 g of KNO_3 in 250 mL of water at 60°C __________

6. 120 g of KNO_3 are dissolved in 100 mL of hot water. The solution is then cooled to 50°C.

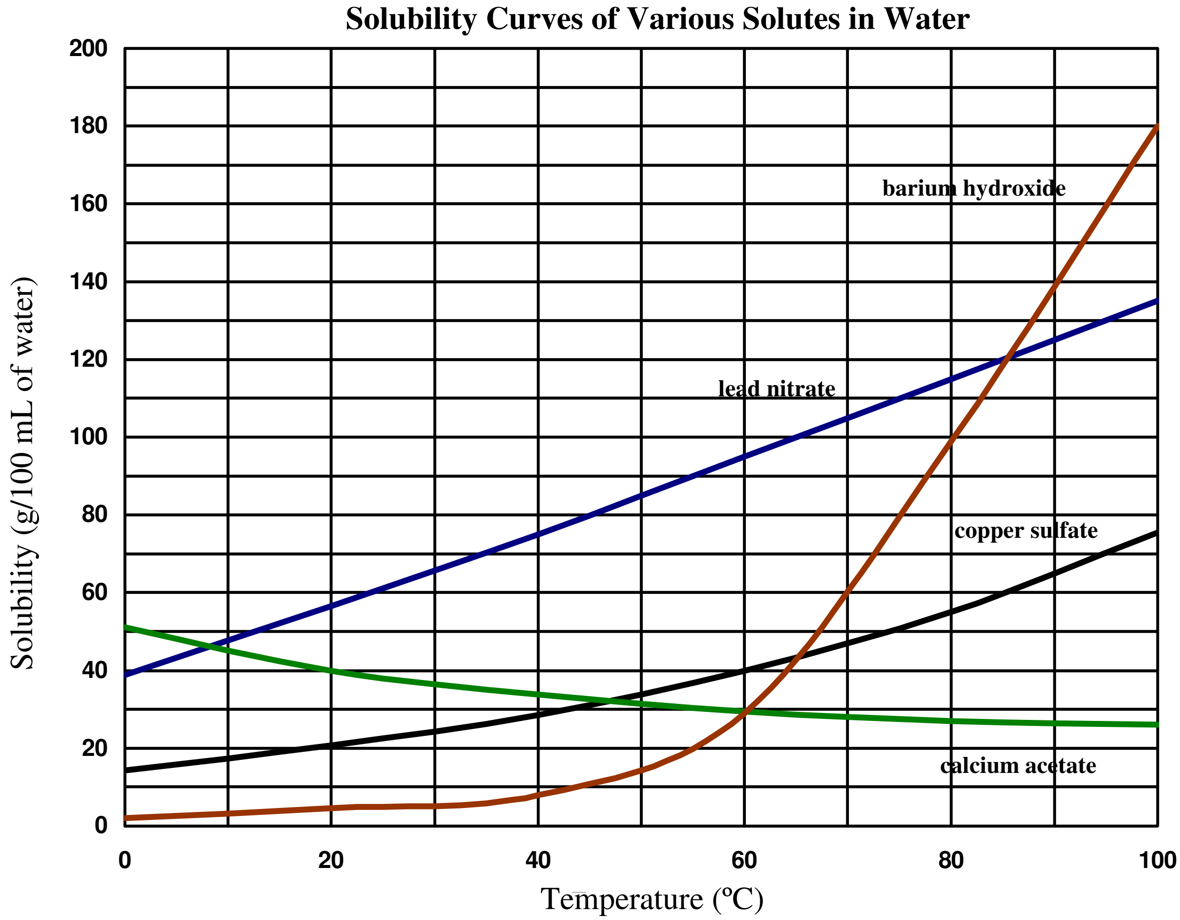
a) What is the solubility of KNO_3 at 50°C ? _________

b) How many grams of solid KNO_3 will crystallize from the solution as it cools?

7. 90.0 grams of KNO_3 are dissolved in 100.0 mL of hot water. The solution is then cooled to 22°C. How many grams of solid will crystallize when the solution is cooled if a tiny seed crystal is added?

Practice Questions: Solubility Curves

1. Define: concentration, dilute solution, concentrated solution, saturated solution, unsaturated solution, super-saturated solution, solubility.



2. From the solubility curves above, how many grams of copper (II) sulfate can dissolve in:
a) 100 mL of water at 40ºC ____________
b) 50 mL of water at 80ºC ____________
c) 10 mL of water at 100ºC ____________
d) 250 mL of water at 60ºC ____________

3. From the solubility curves above, how many grams of barium hydroxide can dissolve in:
a) 100 mL of water at 20ºC ____________
b) 50 mL of water at 90ºC ____________
c) 10 mL of water at 80ºC ____________
d) 250 mL of water at 60ºC ____________

4. From the solubility curves above, what is the minimum temperature required to dissolve:
a) 60 g of $Pb(NO_3)_2$ in 100 mL of water _________
b) 20 g of calcium acetate in 50 mL of water ________
c) 80 g of $CuSO_4$ in 200 mL water _________
d) 35 g of $Ba(OH)_2$ in 25 mL water ________

5. At what temperatures are the solubilities of the following substances equal?
a) copper (II) sulfate and barium hydroxide _______
b) lead (II) nitrate and barium hydroxide ________
c) calcium acetate and lead (II) nitrate _______
d) calcium acetate and copper (II) sulfate ______

6. Are the following solutions saturated (S), unsaturated (U) or super-saturated (SS) at the temperatures below?
a) 100 g of lead nitrate in 100 mL water at 30ºC _____
b) 20 g copper sulfate in 50 mL water at 80ºC _____
c) 15 g of $Ba(OH)_2$ in 25 mL water at 70ºC _____
d) 1 g of $Ca(CH_3COO)_2$ in 10 mL water at 90ºC

7. What is unusual about the solubility curve for calcium acetate?

8. A hot solution of barium hydroxide contains 200 g of solute per 100 mL of water. The solution is cooled to 20^0C. What mass of solid will form as the solution is cooled?

Concentration of Solutions Problems

1. Calculate the % W/W concentration for the following solutions:
a) 75 g of salt in 200.0 g of water
b) 38 g of sugar in 96 mL of water. The density of pure water is 1.0 g/mL.
c) 60.0 g of solute in 400.0 mL of solution. The solution has a density of 1.4 g/mL.

2. What is the % V/V concentration of the following solutions:
a) 40.0 mL of sulfuric acid added to 120.0 mL of distilled water
b) 15.0 mL of pure acetic acid diluted to a final volume of 0.300 L. (1L = 1000 mL)

3. What is the % W/V concentration of the following solutions:
a) 24 g of salt in 72 mL of solution
b) 140.0 g of sodium nitrite in 400.0 L of pickling brine

4. What is the molar concentration of a solution containing:
a) 0.40 mol of solute in 100.0 mL of solution
b) 7.3 g of HCl in 250 mL of solution
c) 160.0 g of sodium carbonate in 5000.0 mL of solution
d) 200.0 g of sucrose ($C_{12}H_{22}O_{11}$) in 100.0 mL of solution

5. Complete the following chart:

Solute	Molar Mass of Solute (g/mol)	Mass (m) in grams	Number of Moles (n)	Volume (V)	Concentration (C) in mol/L
$AgNO_3$			3.50	500.0 mL	
NaCl				1.50 L	0.250 mol/L
NH_4Cl			0.850 mol		3.40 mol/L
KI		120.0 g		2.00 L	
NaOH		9.20 g			2.30 mol/L

6. What mass of solute is dissolved in:
a) 500.0 mL of 6.00 M HCl
b) 2.00 L of 0.100 M sodium hydroxide
c) 125 mL of 0.0200 M potassium permanganate

7. If 250.0 mL of 6.00 M stock solution of NaOH is diluted to a final volume of 1.00 L with water, what is the molarity (molar concentration) of the final solution?

8. How much water must be added to 0.500 L of 12.0 M H_2SO_4 to make a 4.00 M solution?

Answers:

1a) 27% salt W/W; 1b) 28% sugar W/W; 1c) mass of solution = 560 g [m = DxV] then, concentration of solution is 10.7% or 11% W/W
2a) 25.0% V/V; 2b) 5.00 % V/V (you must convert 0.300 L to 300 mL)
3a) 33% W/V; 3b) 0.03500% W/V (400.0 L = 400 000 mL)
4a) 4.0 mol/L; 4b) 0.80 mol/L; 4c) 0.3019 mol/L; 4d) 5.842 mol/L

5.

Solute	Molar Mass of Solute (g/mol)	Mass (m) in grams	Number of Moles (n)	Volume (V)	Concentration (C) in mol/L
$AgNO_3$	169.88 g/mol	595 g	3.50 mol	500.0 mL	7.00 mol/L
NaCl	58.44 g/mol	21.9 g	0.375 mol	1.50 L	0.250 mol/L
NH_4Cl	53.50 g/mol	45.5 g	0.850 mol	0.250 L	3.40 mol/L
KI	166.00 g/mol	120.0 g	0.7229 mol	2.00 L	0.361 mol/L
NaOH	40.00 g/mol	9.20 g	0.230 mol	0.100 L	2.30 mol/L

6a) 109 g of HCl; 6b) 8.00 g of NaOH: 6c) 0.395 g of $KMnO_4$
7) 1.50 M concentration of final solution
8) the final volume is 1.50 L, so you need to add 1.00 L of water to the original 0.500 L

Properties of Acids and Bases

Property	Acids	Bases
Arrhenius Definition		
Examples		
Produced by which type of element or oxide dissolving in water (metals or non-metals)		
Which ion is responsible for their properties?		
Does the aqueous solution conduct electricity?		
Taste		
Skin feel		
Colour with red or blue litmus paper		
Colour with phenolphthalein		
Colour with bromothymol blue		
Reaction with metals		
Reaction with carbonates		
pH		

Label the pH scale:

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14

Reactions of Acids and Bases

Write **balanced** chemical equations for the reactions between the following substances. Include the states of all substances. Be sure that you can name all of the compounds from these equations.

1. HCl (aq) + Li (s)

2. HNO_3 (aq) + Mg (s)

3. $HC_2H_3O_2$ (aq) + K_2CO_3 (aq)

4. H_2SO_4 (aq) + $CaCO_3$ (s)

5. KOH (aq) + HCl (aq)

6. $Ca(OH)_2$ (s) + H_2SO_4 (aq)

7. nitrous acid + zinc metal

8. acetic acid + ammonium hydroxide

9. hypobromous acid + aluminum metal

10. ammonium hydroxide (aq) + hypophosphorous acid

11. HBr (aq) + Na (s)

12. $HClO_4$ (aq) + $LiOH$ (aq)

13. HNO_3 (aq) + $Al(OH)_3$ (s)

14. H_2SO_3 (aq) + $MgCO_3$ (s)

Describing Acids and Bases

There are two terms used to describe acids and bases: ________________________ and _______________.

1. The **concentration** of an acid or base tells us _______________ is dissolved in a certain ____________ of solution. There are many ways to indicate concentration, for example:

- 5 % V/V acetic acid (vinegar) means: ____
- 10 % W/W calcium hydroxide solution means: __________________________________
- 6.0 M HCl (aq) means: ____
- 0.010 M NaOH (aq) means: ____

If the concentration of an acid or base is 6.0 M or more, it is said to be ________________.

If the concentration of an acid or base is 3.0 M or less, it is said to be ____________.

2. The **strength** of an acid or base tells us how well it ____________ (forms ________) and/or ______________________ (____________________) in ___________. The strength of an acid or base depends both on its ________________________________ and its ____________________ in water. We will consider acids and bases separately.

The Strength of Acids
The chemical formulas of acids have ________________ as their first element, indicating that acids are _______________ compounds. Acids do not contain ________ in their pure form.

When acids dissolve in water, the ___________ regions of water molecules interact with __________ parts of the acid molecules. Water causes the acid to form __________ (____________) and then these ions _____________________ (___________________) from the rest of the acid molecule. Because acids ______________ and _________________ into _________ in water, acids are ___________________. However, some acids ionize and dissociate more than others.

Strong acids ionize _____________________________. More than _______ of the acid molecules are converted to _________ in solution. These acids are ____________________ conductors of electricity in solution (_________________________________) and they have _________________ pH (close to ___).

eg. HCl (g) $\xrightarrow{H_2O\ (l)}$

There are ______ (__) common strong acids:

___________________________________ ___________________________________
___________________________________ ___________________________________
___________________________________ ___________________________________

Weak acids ________________________ very much in water (less than _____) so most of the acid is found as the ____________________________.

Weak acids produce _______________ ions in solution, so they are ________ conductors of electricity (poor __________________) and have pH values closer to ____ (_____ to ___________).

eg. HF (l) $\xrightarrow{H_2O\ (l)}$

eg. HCH_3COO (l) $\xrightarrow{H_2O\ (l)}$

If an acid is NOT one of the six strong ones listed above, then it is a __________ acid. Many important biological compounds are weak acids. For example:

The Strength of Bases

The chemical formulas of most bases have a ___________ as their first element, combined with the ________________ ion. Bases are __________ compounds and contain ________ in their pure form.

When bases dissolve in water, the metal and hydroxide ions _______________ (separate). No ____________________________ is required. However, some bases ___________ better than others in water, which affects their strength.

Strong bases dissolve and dissociate almost completely so they are _________________ conductors of electricity (___________ electrolytes) and they have ________________ pH (close to _____).

The ___________ and _______________ of all Group I (_____________________) and Group II (_________________________________) are __________ bases:

________________________________ ________________________________

________________________________ ________________________________

________________________________ ________________________________

eg. NaOH (s) $\xrightarrow{H_2O\ (l)}$

eg. $Ca(OH)_2$ (s) $\xrightarrow{H_2O\ (l)}$

Weak bases are often ___________________ so they do not _________________ very much in water so most of the base is still together as the ____________________________.

eg. $Fe(OH)_3$ (s) $\xrightarrow{H_2O\ (l)}$

$Pb(OH)_2$ (s) $\xrightarrow{H_2O\ (l)}$

There are also a few _________________ molecules that react with water to form hydroxide ions, so these are also weak bases.

eg. NH_3 (g) + H – OH (l) $\rightarrow$

Weak bases produce _____________________ ions in solution, so they are _________ conductors of electricity (poor electrolytes) and have pH values closer to ____ (______ to _____ ish). If a base is not one of the ____________ bases listed above, then it is a _________ base (often because of ___________________________ in water).

The more OH- ions that are free in the solution, the ______________ the base and the __________ the pH.

DO NOT CONFUSE THE WORDS
“STRONG” with “CONCENTRATED” or “WEAK” with “DILUTE”

Classify the following acids and bases as strong or weak and concentrated or dilute:

1.0 M HCl (aq) is _____________________ and __________________

12.0 mol/L HCH_3COO (aq) is ___________________ & ______________

9.0 M H_2SO_4 (aq) is ____________________ & __________________

0.0100 mol/L $H_2C_2O_4$ (aq) is ___________________ & _______________

0.050 M solution of HNO_3 (aq) is _____________________ & __________________

2.0 mol/L solution of $Cu(OH)_2$ (aq) is ___________________ and _________________

6.0 M solution of LiOH (aq) is ______________________ and _________________

1.2 M solution of NH_3 (aq) is _______________________ and _________________

3.0 mol/L solution of $Sr(OH)_2$ (aq) is _______________________ and _________________

Strength, Concentration and pH of Acids and Bases

1. Name the following acids, and then classify them as strong or weak and concentrated or dilute:

Concentration & Chemical Formula	Name of Acid	Strong or Weak?	Concentrated or Dilute?
3.0 M H_2CO_3			
7.0 M HI			
12.0 M H_2SO_3			
1.0 M $HBrO_3$			
15.0 M HCH_3COO			
0.50M HI			
6.0M HF			
0.001M HNO_2			

2. Name the following bases, and then classify them as strong or weak and concentrated or dilute:

Concentration & Chemical Formula	Name of Base	Strong or Weak?	Concentrated or Dilute?
2.0 M $Sr(OH)_2$			
6.0M NH_4OH			
9.0 M CaO			
0.10 M AgOH			
3.0 M LiOH			
0.01 M $Sn(OH)_4$			
8.0 M Na_2O			
1.5 M $Ba(OH)_2$			

3. Circle the acid in each group which is the stronger electrolyte:

a) H_2CO_3 or H_2SO_4
b) HNO_3 or HNO_2
c) HCl or HClO
d) H_2SO_4 or H_2SO_3
e) HBr or $HBrO_2$
f) HF or HI

4. Circle the base in each group which will have the higher pH:

a) NH_4OH or NaOH
b) $Ca(OH)_2$ or $Cd(OH)_2$
c) SrO or SnO
d) AgOH or LiOH
e) Cr_2O_3 or Cs_2O
f) H_2O or K_2O

5. Are the following bases soluble (aq) or insoluble (s) in water?

a) $Ca(OH)_2$:____________
b) $Ni(OH)_3$:___________
c) LiOH:___________
d) $Mn(OH)_2$:____________
e) $Al(OH)_3$:__________
f) NH_4OH: ___________

6. Answer the following questions using the pH values for common substances in the chart:

a) The strongest base is: ____________________________
b) The acid which will be the best conductor of electricity in solution is: ____________________________________
c) Two neutral substances: __________________________ and __________________________
d) One substance that has ionized: ___________________
e) One substance that will be blue with blue litmus paper : ___________________________
f) One substance that will be colourless with phenolphthalein: ________________________
g) One weak acid: ____________________________

Window Cleaner	pH = 11
Lemon juice	pH = 2
Stomach acid (HCl)	pH = 1.5
Tomato juice	pH = 4.7
Oven cleaner (NaOH)	pH = 14
Dill pickles	pH = 3.3
Milk	pH = 6.6
Trisodium phosphate (TSP)	pH = 13
Sea water	pH = 8.4
Blood	pH = 7.4

Practice Questions: Concentrations of Acids and Bases

1. Calculate the volume of 15.0 M HNO_3 stock solution that is required to make 2.5 L of 1.25 M solution.
2. Calculate the mass of solid barium hydroxide that is needed to make 300.0 mL of 0.200 M solution.
3. 75.0 mL of 18.0 M sulfuric acid stock solution is diluted to make 1.00 L. What is the final concentration of this solution?
4. Calculate the final concentration of a solution that is made by dissolving 14.8 g of solid sodium hydroxide in 600.0 mL of solution.
5. 25.0 mL of 3.66 M ammonium hydroxide solution is diluted to make a final solution with a concentration of 1.50 M. What is the volume of the finished solution?
6. A biochemist needs a 0.0250 M solution of citric acid ($H_3C_6H_5O_7$) for an experiment. Citric acid is solid at SATP.

a) Is citric acid a strong or weak acid?

b) To what extent will citric acid ionize in water?

c) What mass of pure citric acid is required to make 680 mL of 0.0250 M solution?

7. Describe the steps that you would follow if you were making 500.0 mL of a 0.200 M solution of calcium hydroxide. Be complete.

Answers:

1. 210 mL of HNO_3 stock solution is needed (rounded from 208 mL, to 2 sig digs)
2. 10.3 g of $Ba(OH)_2$ required
3. 1.35 M is the final concentration
4. 0.617 M
5. 61.0 mL or 0.0610 L is the final volume

6a) weak

6b) it will only slightly ionize (it will be a weak electrolyte)

6c) 3.3 g of citric acid is needed (rounded from 3.266 g, to 2 sig digs)

7. Steps in making 500.0 mL of a 0.200 M $Ca(OH)_2$ solution:

- weigh out 7.41 g of solid $Ca(OH)_2$
- get a clean 500.0 mL volumetric flask, fill it about 2/3s with distilled water
- add the solid $Ca(OH)_2$ to the flask and swirl until it dissolves
- let the solution cool
- add distilled water until the meniscus is on the etched line of the flask. Mix.