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ABSTRACT

This booklet is one of a set of eight designed to be used in a self-paced introductory chemistry course in conjunction with specified textbooks and computer-assisted instruction (CAI) modules. Each topic is introduced with a textbook reading assignment and additional readings are provided in the booklet. Also included are self-tests (and answers), CAI module assignments, and suggested breakpoints for student-teacher consultations. Supplementary reading materials, including filmstrips, are also suggested. Each booklet contains specific cognitive objectives for the unit. This booklet covers three topics concerning solutions: acid-base theory, ionization theory, and stoichiometry. (MH)

ED130857

ILS CHEM PAC No. **6**

SOLUTIONS

by

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West Chester State College
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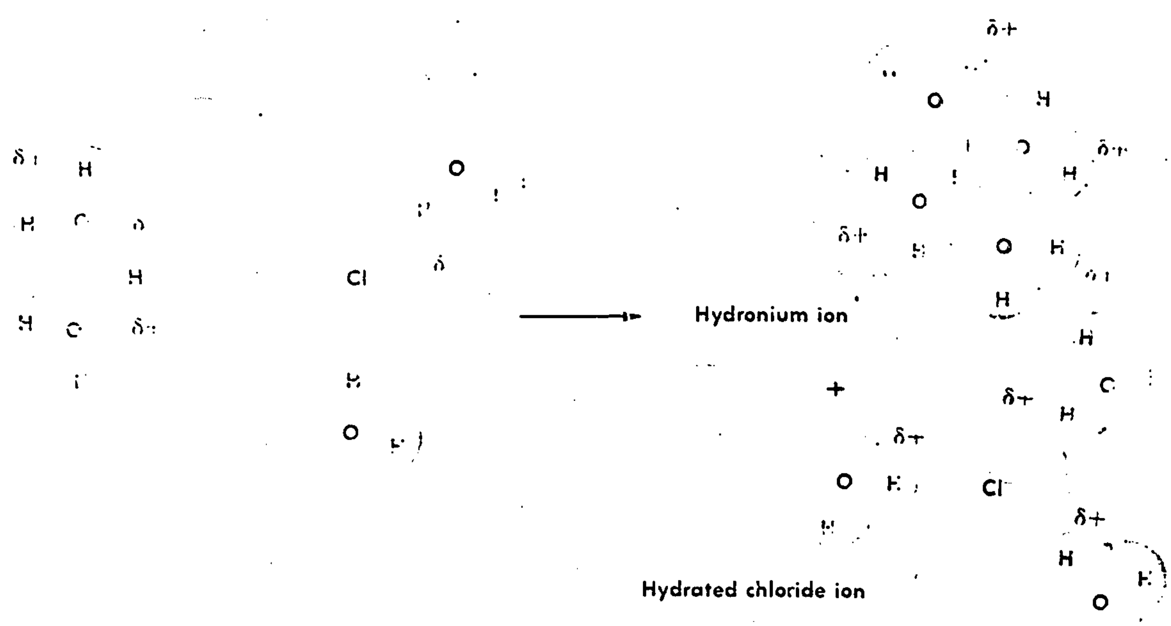
Student No. & Name ....

Date Started ....

Date Completed ....

SE 021 427



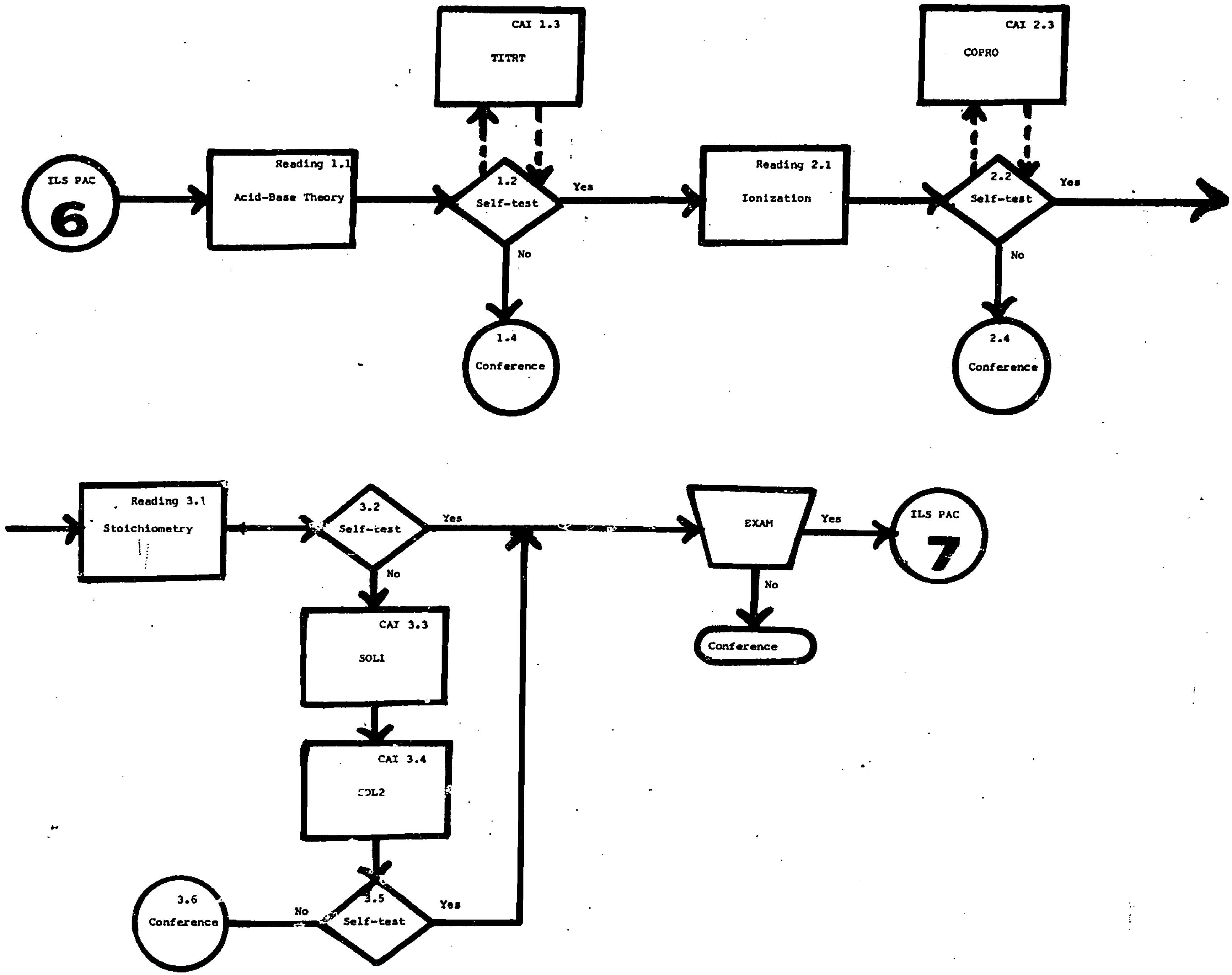
The dipole-dipole interaction between H_2O and HCl leading to ionization.

SIMPLIFIED TABLE OF THE SOLUBILITY OF COMMON SALTS IN WATER AT 20°C

Anion	Cation	Solubility
acetate, chlorate, nitrate	nearly all	soluble
chloride, bromide, iodide	lead(II), silver, mercury(I)	insoluble
	all others	soluble
hydroxide	group I metals, barium, strontium	soluble
	all others*	insoluble
sulfate	mercury(I) and (II), calcium, barium, strontium, silver, lead(II)	insoluble
	all others	soluble
carbonate, phosphate, chromate	group I metals,** ammonium	soluble
	all others	insoluble
sulfide	group I metals, ammonium, magnesium, calcium, barium	soluble
	all others	insoluble

* $Ca(OH)_2$ slightly soluble. ** Li_3PO_4 insoluble.

SOLUTIONS



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OBJECTIVES

Upon completion of the ILS Chem Pac on Solutions the student should be able to

1. Acid-Base Theory

Demonstrate an understanding of acid-base theory by:

A. Given 6 properties, identify 5 of the properties as characteristic of an aqueous acid or base.

B. Given 8 uses and a list of acids and/or bases, match 6 of the acids or bases to the use given.

C. Given 5 pH values, identify 4 of the numerical values as acidic, neutral, or basic.

D. Given a formula or name of 10 compounds, identify 9 of the substances as an acid, base, normal salt, acidic salt, or basic salt.

E. Given 10 definitions and list of acid-base terms, match 9 of the definitions to the term it defines. These terms include the following:

1. acid
2. acidic salt
3. base
4. basic salt
5. buffer
6. hydrolysis
7. neutralization
8. normal salt
9. pH
10. salt

2. Theory of Ionization

A. Demonstrate an understanding of the theory of ionization by defining or identifying such terms as 9 of the following 11 terms:

1. anion
2. anode
3. cathode
4. cation
5. dissociation
6. electrolysis
7. electrolyte
8. hydronium ion
9. ionization
10. ions
11. non-electrolyte

B. Predict the qualitative effect on the boiling point or freezing point of a solution that would result from varying the concentration or composition of any given solution.

3. Stoichiometry

Determine the concentration of a solution if

A. Given the amount of solute (in moles, grams, or equivalents) in a given volume of a solution, calculate the molarity or the normality of the solution in 8 out of 10 such solutions.

B. Given the volume and molarity or normality of a solution, calculate the amount of solute in moles, grams, or equivalents in 8 out of 10 such solutions.

ILS Chem Pac 6 - Solutions [or "Who Has the Proton?"]

Reading 1.1a - Read pages 188-196 in Medeiros, pages 156-173 in Sackheim & Schultz, and pages 135-152 in Holum.
Notes:

In the past, acids and bases had been defined operationally. Acids were described as compounds that produced hydrogen ions in water solution and bases produced hydroxide ions. In addition, acids have a sour taste. Blue litmus paper turns red in acids. Acids react with metals above hydrogen in the activity series to produce hydrogen gas. Basic solutions are neutralized by acids. Neutralization may be defined as the reaction between $H^+(aq)$ and $OH^-(aq)$ to form water:

$$H^+ (aq) + OH^- (aq) = H_2O (l)$$

Bases, in turn, have a bitter taste. Red litmus turns blue in basic solutions. Bases react with heavy metal ions to form insoluble hydroxides or oxides. For example:

$$Fe^{3+} (aq) + 3\ OH^- (aq) = Fe(OH)_3 (s)$$

Acid solutions are neutralized by bases.

Self-test 1.2a

Identify the following properties as characteristic of an aqueous acid or base:

1. produce H^+ in water
2. produce OH^- in water
3. bitter taste
4. sour taste
5. turns blue litmus paper red
6. turns red litmus paper blue

Reading 1.1b

Acids are used industrially, in laboratory work, and medically. Hydrochloric acid ....(1)[write formula] in the gastric juices aids in digestion of proteins. Nitric acid .... (2) causes skin to turn yellow--a laboratory test for protein. Hypochlorous acid .... (3) is used as a disinfectant. Boric acid .... (4) was widely used as an antiseptic. Acetyl salicylic acid [common name is .... (5)] is widely used as a .... (6) [analgesic] and as an antipyretic [.......] (7).

Sodium hydroxide .... (8), also known as lye, is used to remove fats and grease from clogged drains. Calcium hydroxide .... (9), commonly known as lime water, is used as an antacid for the stomach. Magnesium hydroxide .... (10), commonly known as milk of magnesia, is used as a laxative. Ammonium hydroxide .... (11), also called spirits of ammonia, is used as a heart and respiratory stimulant.

The answers to Reading 1.1b are:

1. HCl	6. pain killer
2. HNO_3	7. to reduce fever
3. HClO	8. NaOH
4. H_3BO_3	9. $Ca(OH)_2$
5. aspirin	10. $Mg(OH)_2$
	11. NH_4OH

Self-test 1.2b

Match the following acids or bases with their respective use.

use	compound
1. digestion of protein	a. NaOH
2. lab test for protein	b. $Ca(OH)_2$
3. dissolves fat & grease	c. $Mg(OH)_2$
4. stomach antacid	d. NH_4OH
5. disinfectant	e. HCl
6. analgesic	f. HNO_3
7. laxative	g. HClO
8. heart & respiratory stimulant	h. aspirin

Reading 1.1c

The term pH is used to indicate the strength of an acid or base. A pH of 7 indicates a neutral solution; pH values below 7, an acidic solution; and pH values above 7, a basic solution. A strong acid would have a pH around 1, while a pH of 5 indicates a weakly acidic solution. A strong base would be a pH of 13 while a pH of 8 indicates a weakly basic solution. Blood, for example, has a pH range of 7.35-7.45. A solution which resists a change in pH, such as blood, is called a buffer.

Self-test 1.2c

Identify the following pH values as acidic, neutral, or basic.

1. 1.5
2. 3.7
3. 6.2
4. 7.5
5. 9.3

Reading 1.1d

The classical Arrhenius definition of an acid--compounds that yield hydrogen ions in water--is inadequate in explaining why some metal ions test as acids in aqueous solutions and anions, such as CN^-, behave like bases. Typical acids and bases are:

$$HCl \longrightarrow H^+ + Cl^- \text{ (in water)}$$

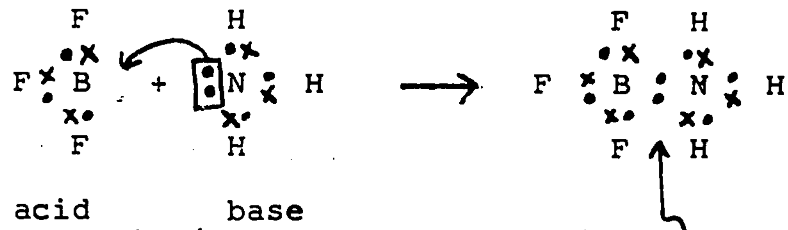
$$NaOH \longrightarrow Na^+ + OH^- \text{ (in water)}$$

The Bronsted-Lowry theory defined an acid as a proton donor and a base as a proton acceptor. The proton transfer can be illustrated as follows:

$$HCl\ (g) + H_2O\ (l) = H_3O^+\ (aq) + Cl^-\ (aq)$$

Although the hydronium ion is usually written as above, H_3O^+, experimental evidence indicates that more than one water molecule is bonded to the transferred proton. Other chemists use the symbol $H^+(aq)$.

A still broader definition, proposed by Lewis, defines an acid as an electron pair acceptor and a base as an electron pair donor. The common example of a Lewis acid-base reaction which does not fit the Bronsted theory is BF_3 and NH_3.



acid (electron pair acceptor) base (electron pair donor) (covalent bond)

More recently (see Journal of Chemical Education, September and October, 1968, pp 581-587 and 643-648), Pearson has proposed a theory of hard and soft acids and bases. While the various definitions are not wrong (in the hard, inflexible sense of that word), other definitions are more fruitful in explaining and predicting what actually happens in the laboratory. This is part of the on going nature of chemistry.

Self-test 1.2d

Classify the following compounds as acid, base, or salt (including type of salt).

1.	H_2SO_4	6.	$Ca(NO_3)_2$
2.	$Ca(OH)_2$	7.	$Mg(OH)_2$
3.	K_2SO_4	8.	H_3PO_4
4.	HNO_3	9.	K_2HPO_4
5.	NaH_2PO_4	10.	$Bi(OH)(NO_3)_2$

Reading 1.1e

Salts are formed when an acid reacts with a base, for example:

$$\underset{\text{acid}}{HCl} + \underset{\text{base}}{NaOH} = \underset{\text{salt}}{NaCl} + \underset{\text{water}}{H_2O}$$

This is also known as neutralization. In the laboratory, this reaction is called a titration. The reverse reaction, a double displacement reaction in which water is a reactant, is called hydrolysis, as follows:

$$\underset{\text{salt}}{NH_4Cl} + \underset{\text{water}}{H_2O} \underset{\text{neutralization}}{\overset{\text{hydrolysis}}{\rightleftharpoons}} \underset{\text{base}}{NH_4OH} + \underset{\text{acid}}{HCl}$$

A normal salt, such as NaCl, contains no hydrogen ions. Acid salts, such as $NaHCO_3$, contain at least one hydrogen ion. A basic salt, such as $Bi(OH)_2NO_3$ contains a hydroxyl group (OH^-).

Self-test 1.2e

Match the following terms with the items supplied.

1. acid	a. H^+ concentration
2. acidic salt	b. $HCl + NaOH = NaCl + H_2O$
3. base	c. HAc + NaAc
4. basic salt	d. NaOH
5. buffer	e. HCl
6. hydrolysis	f. NaCl
7. neutralization	g. $NH_4Cl + H_2O = NH_4OH + HCl$
8. normal salt	h. $Bi(OH)_2NO_3$
9. pH	i. NaH_2PO_4
10. salt	

Conference 1.4

If you missed more than one or two questions in any part of Self-test 1.1, please consult your instructor. This is the only NO route available at this time.

Date:

Notes:

CAI 1.3 - TITRT - Titration

This is NOT a NO route. It is an additional and optional excursion in which the computer module simulates experiments applying acid-base titration techniques. The six titration techniques are:

1. Standardize an acid.
2. Standardize a base.
3. Titrate a strong base with an unknown weak acid.
4. Titrate a strong acid with an unknown weak base.
5. Analyze a sample for base content.
6. Analyze a sample for acid content.

To use this module you must first obtain an unknown number from the instructor, and a separate two page handout.

Date Completed:

Reading 2.1 - Read pages 175-188 in Medeiros, pages 137-153, and 175-180 in Sackheim & Schultz. and pages 123, 134 & 153 in Holum.
Notes:

In the previous reading we noted that the formation of hydrogen ions in solution is a characteristic of acids. An electrolyte may be defined as any substance that produces ions in water solution and whose water solutions conduct electricity. Hydrogen chloride ionizes almost completely in dilute solution and is known as a strong electrolyte. Compounds such as sugar do not ionize appreciably, although sugar does dissolve in water, and thus are known as non-electrolytes. The passage of an electric current through water is called electrolysis. The positive electrode is called the anode. The ions attracted to the anode are called anions and are negatively charged. Likewise, the negative electrode is the cathode and the positively charged ions attracted to the cathode are called cations. Thus, in a salt solution, the sodium ion, Na^+, is a cation and the chloride ion, Cl^-, is an anion.

Electrolytes have an unusual effect on the boiling point and the freezing point of a solution. Any water solution has a boiling point above 100 °C and a freezing point below 0 °C. For example, a one molal sugar solution boils at 100.52 °C and freezes at -1.86 °C. Sugar, you recall, is a non-electrolyte. If an electrolyte, such as sodium chloride, is the solute, the increase in the boiling point of the water containing the salt will be approximately twice that for the sugar solution. Likewise, the freezing point of the salt solution will be lowered approximately twice as much as that of the sugar solution.

The abnormal effect of electrolytes on the boiling point and on the freezing point of solutions is said to be due to the increased number of particles (ions) resulting from the dissociation or ionization of the electrolyte. In the example of sodium chloride, one formula unit (NaCl) yields one unit of sodium ions (Na^+) and one unit of chloride ions (Cl^-).

$$NaCl \text{ ---- } Na^+ + Cl^-$$

Sugar, as a non-electrolyte, does not increase the number of particles present when it dissolves. Properties that depend on the number of particles present (such as B.P. and F.P.) are called colligative properties.

Self-test 2.2

Match the following terms with the items supplied.

1. anion
2. anode
3. cathode
4. cation
5. dissociation
6. electrolysis
7. electrolyte
8. hydronium ion
9. ionization
10. ions
11. non-electrolyte

a. non-conductor of electricity
b. hydrated proton
c. formation of ions in aqueous solutions
d. positive electrode
e. SO_4^{2-}
f. charged atom or group of atoms
g. water solution conducts an electric current
h. NH_4^+
i. negative electrode
j. formation of ions
k. passage of an electric current

****

12. Predict the approximate boiling points and freezing points of a 1.0 molal solution of alcohol and a 1.0 molal solution of sodium nitrate.

Conference 2.4

If you are still having difficulty with the theory of ionization, please consult your instructor. This is the only NO route available at this time.

Date:

Notes:

CAI 2.3 - COPRO - Colligative Properties

This is NOT a a NO route. It is an additional and optional excursion in which the computer module simulates an experiment based upon colligative property theory. You are asked to determine the molecular weight of an unknown compound through the freezing point depression or boiling point elevation of a solution. You select:

a. the solvent (water, benzene, naphthalene, or camphor);
b. measurement of the freezing point or boiling point (the molal constant is then provided);
c. grams of the solvent to be used; and
d. grams of the unknown to be added.

The computer then outputs the new freezing (or boiling) point of the theoretical solution which includes random experimental error. You are then asked to perform a second set of measurements for verification and to calcualte the molecular weight of the unknown and identify the unknown by number.

The unknown compound is randomly selected from the following 10 compounds given below with their molecular weights:

1. Dioxane - 88.1
2. Methylnitrate - 77
3. Nicotine - 162.2
4. Maltose - 360
5. Glycol - 62.1
6. Glycerin - 92.1
7. Hexose - 180
8. Nitroglycerin - 227.1
9. Progesterone - 314
10. Ribose - 150

Again no units should be included on any numerical input. The relationship involved here is:

$$\Delta T = K \times \frac{\text{grams solute / MW solvent}}{\text{grams solvent}} \times 1000 \text{ g solvent}$$

where ΔT = change from normal boiling or freezing point and

K = constant characteristic for each solvent

Reading 3.1 - Read pages 130-137 in Sackheim & Schultz, and pages 119-122 and 171 & 172 in Holum.
Notes:

A solution is a homogeneous mixture of two or more substances. The material that dissolves the other is called the solvent and the material that it dissolves is called the solute. Thus salt is a solute dissolved in water a solvent, to make a salt solution. An aqueous solution is one in which water is the solvent.

Chemists express the concentration of a solution in several ways. A molar solution is one which contains one mole or one gram molecular weight of solute per liter of solution. Thus if we take one mole of NaOH (23 + 16 + 1 = 40 g/mole) and dissolve it in enough water to make one liter of solution, we will have a one molar or 1 M solution of NaOH in water. If we had taken 20 g of NaOH (o.5 mole) in the above solution we would have a 0.5 M solution and 80 g of NaOH in one liter of solution is a 2.0 M solution. Likewise, if we take one mole of NaOH but dissolve it in enough water to make 500 ml (0.5 liter) of solution, we will have a 2.0 M solution. This is true because one mole in half a liter is the same as two moles in one liter which is 2 M.

Another solution concentration expression is normality. A normal solution is one which contains one gram equivalent weight of solute per liter of solution. By definition, a gram equivalent weight is the weight in grams of a substance that will combine with or displace 1.008 g of hydrogen. To find the equivalent weight of an acid, we divide the gram molecular weight by the number of hydrogen equivalents present. Thus, for H_2SO_4 we divide 98 g (gram molecular weight) by 2 (number of hydrogen equivalents) so that the equivalent weight of H_2SO_4 is 49 g/equivalent. The equivalent weight of a base is calculated by dividing the gram molecular weight by the number of hydroxyl groups (OH^-) present. Thus, for $Mg(OH)_2$ we divide 58 g (gram molecular weight) by 2 (number of OH^-) so that the equivalent weight of $Mg(OH)_2$ is 29 g/equivalent.

It is not necessary to calculate both the molarity and normality of a given solution because they both depend on the same molecular weight. For example, a 1 M NaOH solution is also 1 N and a 1 M H_2SO_4 solution is also 2 N. Thus, for a univalent compound molarity = normality. For a divalent compound there are always twice as many equivalent weights as molecular weights in any given amount.

The molar concentration of a solution is based on the <u>volume</u> of solvent. Another concentration expression is based on the mass of the solvent. A <u>molal</u> solution contains one mole of solute per 1000 g of solvent. Note that the basis is 1000 grams of solvent, not solution. Molal solutions are useful in determining colligative properties such as freezing points and boiling points.

Self-test 3.2

How many grams of H_2SO_4 are required to make 1.00 liter of a 2.00 M solution?

First we calculate the molecular weight of H_2SO_4 which is ...... (1) g/mole. Thus, 98 g of H_2SO_4 per liter of solution is equivalent to a ...... (2) M solution. To obtain a 2.00 M solution we multiply the weight of one mole by ...... (3) to obtain ...... (4) g of H_2SO_4 per liter of solution to make a 2.00 M solution.

What will be the molarity if 9.8 grams of H_2SO_4 are dissolved to make 500 ml of solution?

From dividing the weight in grams by the gram molecular weight we see that 9.8 g of H_2SO_4 is equivalent to ...... (5) moles. In one liter of solution this would be 0.1 M. However, in 500 ml of solution the concentration of 9.8 g H_2SO_4 is ...... (6) M.

Calculate the mass of solute required to make each of the following solutions:

7. sodium carbonate, one liter of 0.500 M Na_2CO_3
8. sodium nitrate, 500 ml of 0.200 M $NaNO_3$
9. 10.6 grams of Na_2CO_3 in 2.00 liter of solution
10. 500 ml of solution containing 170 g of $NaNO_3$

If you missed more than one of the above problems, take the NO route (CAI 3.3)

CAI 3.3 - SOL1 - Solution Concentration

This module applies the mole concept to calculating molarity and molality. Eight different problems of three types in calculating either the molarity or molality of a given solution are presented. Tutorial cues are available.

Parameters are randomly generated and this module may be repeated.

Date Completed:

CAI 3.4 - SOL2 - Solution Concentration

This module applies the mole concept to solution concentrations and normality calculations. Review problems include calculating the mole weight, number of moles, and molarity. New problems involve the concept of equivalent weight, number of equivalents in a given weight of compound, and the normality of solutions.

Any number of problems may be worked. The control commands SKIP and STOP are operational on all problems throughout this module.

Date Completed:

Self-test 3.5

Computer module SOL3, Solution Stoichiometry, will be Self-test 3.5. This is a tutorial practice module on solution stoichiometry with a review on equivalents and normality. Eight problems are presented initially but additional problems may be worked. Five out of the eight problems should be solved correctly.

This module may be repeated. The control commands SKIP and STOP are operational in this module.

Date Completed:

Conference 3.6

If you are still having difficulty with solution stoichiometry, please see your instructor.

Date:

Notes:

EXAM

ILS Pac 6 Exam will consist of 15 questions.

Objective 1 - Acid-Base Theory

a. Properties - 2 questions

b. Uses - 1 question

c. pH - 3 questions

d. Identify - 4 questions

e. Definitions - 1 question

Objective 2 - Ionization

a. Theory - 2 questions

b. B.P. & F.P. - 2 questions

Objective 3 - Stoichiometry - conference and/or SOL3

See ILS Pac 0 (Student Directions) for Grading System Equivalents. Please remember that although the Exam is necessary for a grade it may not be sufficient. You may also be asked to have a final conference with your instructor.

CONFERENCE

Date:

Notes:

SUPPLEMENTARY MATERIAL

Objective 1 - Acid-Base Theory

Audio Tape: Acids, Alkalis and Salts

Audio-Tape B2: Introduction to Acids and Bases.

Audio-Tape A4: pH Calculations for Aqueous Solutions

Program Tape #16: Acid-Base Theory: States of Matter

Objective 2 - Theory of Ionization

Audio-Tape A5: Principles and Applications of Electrochemistry

Objective 3 - Stoichiometry

Program Tape #9: Expressing Concentrations of Solutions

Filmstrip-Tape #896: Preparing Percent, Molar and Normal Solutions

ANSWERS

Self-test 1.1a

1. acid
2. base
3. base
4. acid
5. acid
6. base

Self-test 1.1b

1. e
2. f
3. a
4. b
5. g
6. h
7. c
8. d

Self-test 1.1c

1. acid
2. acid
3. acid
4. base
5. base

Self-test 1.1d

1. acid
2. base
3. normal salt
4. acid
5. acid salt
6. normal salt
7. base
8. acid
9. acid salt
10. basic salt

Self-test 1.1e

1. e
2. i
3. d
4. h
5. c
6. g
7. b
8. f
9. a
10. f

Self-test 2.2

1. e
2. d
3. i
4. h
5. c
6. k
7. g
8. b
9. j
10. f
11. a
12. alcohol: B.P. = 100.52 °C and F.P. = -1.86 °C
    salt: B.P. = 101.04 °C and F.P. = - 3.72 °C

Self-test 3.2

1. 98
2. 1.00
3. 2
4. 196
5. 0.1
6. 0.2
7. 53 g
8. 8.5 g
9. 0.05 M
10. 4 M

SOME ELECTROLYTES AND NONELECTROLYTES

Strong Electrolytes		**Ions or Molecules in Solution**
A. SOLUBLE IONIC COMPOUNDS		
$NaCl$	$\xrightarrow[\text{dissociation}]{\sim 100\%}$	$Na^+(aq) + Cl^-(aq)$
KNO_3		$K^+(aq) + NO_3^-(aq)$
$NaOAc$		$Na^+(aq) + OAc^-(aq)$
$CuSO_4$		$Cu^{2+}(aq) + SO_4^{2-}(aq)$
B. STRONG ACIDS		
HCl	$\xrightarrow[\text{ionization}]{\sim 100\%}$	$H^+(aq) + Cl^-(aq)$
$HClO_4$		$H^+(aq) + ClO_4^-(aq)$
HNO_3		$H^+(aq) + NO_3^-(aq)$
H_2SO_4		$H^+(aq) + HSO_4^-(aq)$
HBr		$H^+(aq) + Br^-(aq)$
HI		$H^+(aq) + I^-(aq)$
Weak Electrolytes		
HNO_2	$\xrightarrow[\text{ionization}]{\text{slightly less to much less than } 1\%}$	$HNO_2(aq) + \text{few } H^+(aq) + NO_2^-(aq)$
H_2SO_3		$H_2SO_3(aq) + \text{few } H^+(aq) + HSO_3^-(aq)$
$HOAc$		$HOAc(aq) + \text{few } H^+(aq) + OAc^-(aq)$
HF		$HF(aq) + \text{few } H^+(aq) + F^-(aq)$
H_2S		$H_2S(aq) + \text{few } H^+(aq) + HS^-(aq)$
Nonelectrolytes		
$C_{12}H_{22}O_{11}(s)$ (table sugar—sucrose)	$\xrightarrow[\text{ionization}]{\text{no appreciable}}$	$C_{12}H_{22}O_{11}(aq)$
$CH_3OH(l)$ (wood alcohol—methanol)		$CH_3OH(aq)$
$CH_3CH_2OH(l)$ (grain alcohol—ethanol)		$CH_3CH_2OH(aq)$
$CO(NH_2)_2(l)$ (urea)		$CO(NH_2)_2(aq)$
$CH_2OHCH_2OH(l)$ (antifreeze—ethylene glycol)		$CH_2OHCH_2OH(aq)$