Chem 121: General Chemistry II

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Chem 121: General Course Topics

- Ionic equilibria
- Thermodynamics
- Electrochemistry
- Molecular orbital theory
- Coordination chemistry
- Introduction to organic chemistry
- Spectroscopy - visible, UV, IR, NMR
- Chemical kinetics
- Introduction to nuclear chemistry
- Qualitative analysis
- Quantitative analysis

Chem 121 Topics: Part 1

Ionic equilibria

- Acid base review
- Buffers and titration curves
- Solubility product
- Selective precipitation
- Dissolving precipitates
- Formation constants for complex ions

Qualitative analysis (Laboratory)

- Separation & Identification of selected ions
- Application of the principles of ionic equilibria, oxidation-reduction, and complex ion formation

Chem 121: General Chemistry II

[Review of the Essential Principles
from General Chemistry I]

Chem 121: Essentials

General Review Topics (Part 1)

(Each requires a high degree of personal proficiency):

Nomenclature (Polyatomic Ions), Reactions, Stoichiometry, Limiting reagent, Net Ionic Equations, Aqueous Solutions/ Solubility, Acids/ Bases, Equilibria

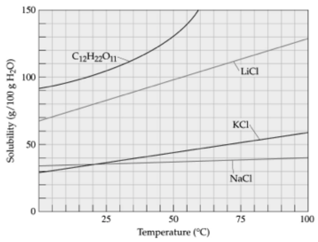
Review: (Workshops/ Worksheets)

1) Ions in Solution; 2) Acids-Bases, Equilibria

Solutions

- Homogeneous solutions are comprised of **solute**(s), the substance(s) dissolved, [The lesser amount of the component(s) in the mixture], and
- **solvent**, the substance present in the largest amount.
- Solutions with less solute dissolved than is physically possible are referred to as "**unsaturated**". Those with a maximum amount of solute are "**saturated**".
- Occasionally there are extraordinary solutions that are "**supersaturated**" with more solute than normal.

Concentration and Temperature



Relative Solution Concentrations:
Saturated
Unsaturated
Supersaturated

Solution Concentration

- *The solution's concentration is a measure of the amount of solute present.*
- *Concentration is expressed in several ways. One of the most important is molarity **(M)**.*

Molarity (M) = Moles solute / Liter Solution

- *An important relationship is **M x $V_{solution}$= mol***
- *This relationship can be used directly in mass calculations of chemical reactions.*

QUESTION #R.1

How many moles of NaCl are contained in 350. mL of a 0.250 M solution of sodium chloride?

A. 0.250 mol
B. 0.350 mol
C. 0.700 mol
D. 87.5 mmol
E. None of these

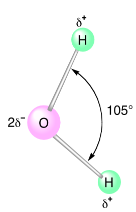
QUESTION #R.2

How many grams of NaCl are contained in 350. mL of a 0.250 M solution of sodium chloride?

A. 41.7 g
B. 5.11 g
C. 14.6 g
D. 87.5 g
E. None of these

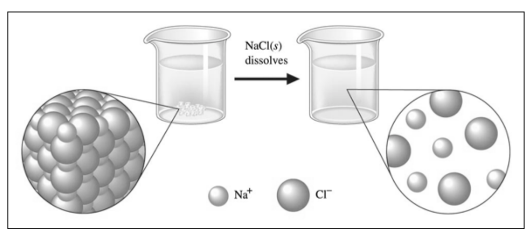
Water : "The Universal" Solvent

Review: Ions in Solution



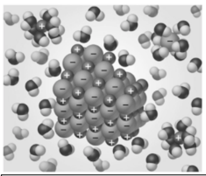
http://www.dhmo.org

Sodium Chloride Readily dissolves in water

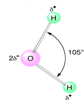


~ 35 g in 100 mL H_2O @ room temperature

Water completely dissolving an ionic solid



Solution Equilibrium

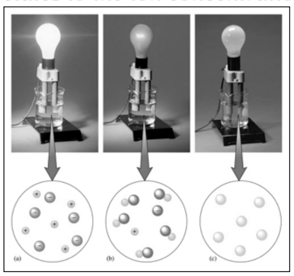


Solution Concentration (Dilution)

- *The following formula can be used in dilution calculations:*

  $M_1V_1 = \text{moles} = M_2V_2$
- *A concentrated stock solution is much easier to prepare and then dilute rather than preparing a dilute solution directly. Concentrated sulfuric acid is 18.0M. What volume would be needed to prepare 250.mL of a 1.50M solution?*

Conductivity of Aqueous Solutions relates to the ion concentration



Strong Weak Non-

Electrolytes, Ions and Solubility

- *Almost all ionic compounds and a few molecular compounds are strong electrolytes.*
- *Several molecular compounds are weak conductors, most are non-conductors.*
- *Conductivity is directly related to the amount of ionization, i.e. ions in solution. Table salt, sodium chloride, is completely ionized:*

$$NaCl_{(s)} + H_2O_{(l)} \longrightarrow NaCl_{(aq)} \longrightarrow Na^+_{(aq)} + Cl^-_{(aq)}$$

0.10M

0.00M 0.10M 0.10M

Electrolytes, Ions and Solubility

- *Which is potentially a better electrolyte, a 0.10M solution of calcium chloride or a 0.10M solution of sodium chloride?*

Hint:

- $CaCl_{2(s)} + H_2O_{(l)} \longrightarrow CaCl_{2(aq)} \longrightarrow Ca^{2+}_{(aq)} + 2\,Cl^-_{(aq)}$

  0.10M

Electrolytes, Ions and Solubility

- *Some molecular compounds like acetic acid ionize partially (dissociate) in water*

$$HC_2H_3O_{2\,(l)} + H_2O_{(l)} \rightleftarrows H_3O^+_{(aq)} + C_2H_3O_2^-{}_{(aq)}$$

0.1000M

0.09987M 0.00013M

- *Sugars like sucrose are non-ionic, molecular compounds that dissolve but produce no ions.*

$$C_{12}H_{22}O_{11\,(S)} + H_2O_{(l)} \longrightarrow C_{12}H_{22}O_{11\,(aq)}$$

Acid/Base Equilibrium

Workshop: Review Acids-Bases, Equilibrium

- *$HA(aq) + H_2O(l) \rightleftarrows H_3O^+(aq) + A^-(aq)$*

acid 1 — base 2 (conj acid 2) — conj base 1

- ***conjugate acid***: *formed when the proton is transferred to the base.*
- ***conjugate base***: *everything that remains of the acid molecule after a proton is lost.*

QUESTION #R.3

Which **does not** constitute a conjugate acid-base pair?

A) H_3PO_4 / $H_2PO_4^-$ B) $H_2PO_4^-$ / PO_4^{3-}

C) HPO_4^{2-} / PO_4^{3-} D) $H_2PO_4^-$ / HPO_4^{2-}

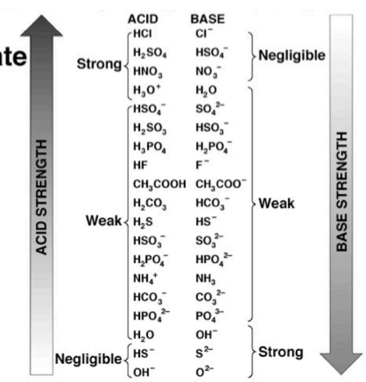
(K_a) Acid Dissociation Constant

- $HA(aq) + H_2O(l) \rightleftarrows H_3O^+(aq) + A^-(aq)$

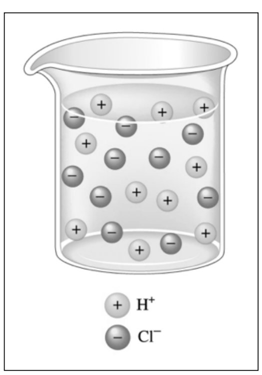
$$K_a = \frac{[H_3O^+][A^-]}{[HA]} = \frac{[H^+][A^-]}{[HA]}$$

- $HA(aq) \rightleftarrows H^+(aq) + A^-(aq)$

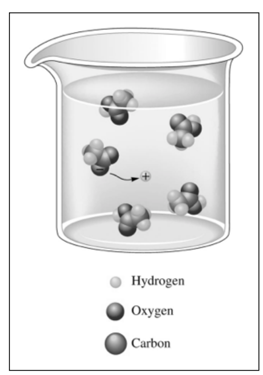
Strengths of Conjugate Acid-Base Pairs



Strong acids such as HCl are completely ionized $K_a >>> 1$ ($K_a \approx \infty$)



Weak acids such as acetic acid ($HC_2H_3O_2$) only partially ionize ($K_a \leq 1$)



QUESTION #R.4

Which of the following is a strong acid?

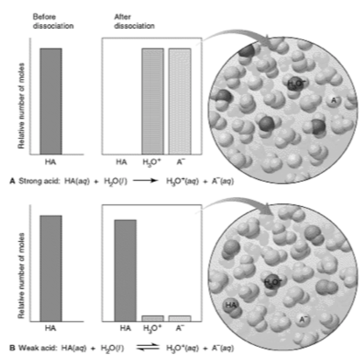
A. HF
B. KOH
C. $HClO_4$
D. HClO
E. HBrO

QUESTION #R.5

Nitric acid, HNO_3, is considered to be a strong acid whereas nitrous acid, HNO_2, is considered to be a weak acid. Which of the statements here is fully correct?

A. Nitric acid has an aqueous equilibrium that lies far to the right and NO_3^- is the conjugate base, which is neutral.
B. Nitric acid has a stronger conjugate base than nitrous acid.
C. The dissociation of nitrous acid compared to an equal concentration of nitric produces more H^+.
D. The equilibrium of nitrous acid lies far to the left and the conjugate base is weaker than the conjugate base of nitric acid.

The Extent of Dissociation for Strong versus Weak Acids



QUESTION #R.6

What are the **major species** present in an aqueous solution of 1.0 M CH_3COOH?

I) CH_3COOH II) H_2O III) H_3O^+
IV) CH_3COO^- V) OH^-

A) I and II **B) II, III, and IV**

C) I, II, III, and IV **D) I, II, III, IV, and V**

Weak Acids

- *Weak acids are only partially ionized in solution and a certain undissociated amount of HA remains at equilibrium.*

$$HA(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + A^-(aq)$$

$$HA(aq) \rightleftharpoons H^+(aq) + A^-(aq)$$

$$K_a = \frac{[H_3O^+][A^-]}{[HA]} \quad \text{or} \quad K_a = \frac{[H^+][A^-]}{[HA]}$$

- *K_a is the acid dissociation constant, which is different for each acid.*

Weak Acids: eg. $HC_2H_3O_2$

- *Acetic acid, a weak acid, is only partially ionized to hydronium and acetate ions in aqueous solution; a certain undissociated amount of acetic acid remains at equilibrium.*

Acid Ionization Equilibrium

Conjugate Acids & Bases

Some Conjugate Acid–Base Pairs

Acid	K_a	Base	K_b
HNO_3	(Strong acid)	NO_3^-	(Negligible basicity)
HF	6.8×10^{-4}	F^-	1.5×10^{-11}
$HC_2H_3O_2$	1.8×10^{-5}	$C_2H_3O_2^-$	5.6×10^{-10}
H_2CO_3	4.3×10^{-7}	HCO_3^-	2.3×10^{-8}
NH_4^+	5.6×10^{-10}	NH_3	1.8×10^{-5}
HCO_3^-	5.6×10^{-11}	CO_3^{2-}	1.8×10^{-4}
OH^-	(Negligible acidity)	O^{2-}	(Strong base)

$K_a \times K_b = ?$

$K_a \times K_b = K_w$

$K_w = [H^+][OH^-] \approx 1.00 \times 10^{-14}$

Values of K_a for Some Common Monoprotic Acids

Formula	Name	Value of K_a*
HSO_4^-	Hydrogen sulfate ion	1.2×10^{-2}
$HClO_2$	Chlorous acid	1.2×10^{-2}
$HC_2H_2ClO_2$	Monochloracetic acid	1.35×10^{-3}
HF	Hydrofluoric acid	7.2×10^{-4}
HNO_2	Nitrous acid	4.0×10^{-4}
$HC_2H_3O_2$	Acetic acid	1.8×10^{-5}
$[Al(H_2O)_6]^{3+}$	Hydrated aluminum(III) ion	1.4×10^{-5}
$HOCl$	Hypochlorous acid	3.5×10^{-8}
HCN	Hydrocyanic acid	6.2×10^{-10}
NH_4^+	Ammonium ion	5.6×10^{-10}
HOC_6H_5	Phenol	1.6×10^{-10}

↑ Increasing acid strength

Percent Ionization

- *Percent ionization is a way to assess relative acid strengths.*
- *For the reaction*

$$\mathbf{HA}(aq) + \mathbf{H_2O}(l) \rightleftharpoons \mathbf{H_3O^+}(aq) + \mathbf{A^-}(aq)$$

$$\%\ \text{ionization} = \frac{[H^+]_{eqm}}{[HA]_0} \times 100$$

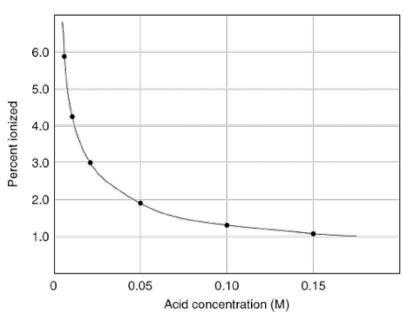
- *Percent ionization relates the* $\mathbf{H_3O^+}$ (aq) *equilibrium concentration,* $[\mathbf{H^+}]_{eqm}$*, to the initial* $\mathbf{HA}(aq)$ *concentration,* $[\mathbf{HA}]_0$.

Weak Acids

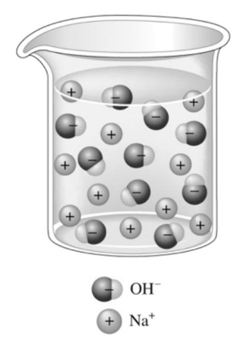
- *The higher percent ionization, the stronger the acid.*
- *Percent ionization of a weak acid decreases as the molarity of the solution increases.*
- *For acetic acid, 0.05* M *solution is 2.0 % ionized whereas a 0.15* M *solution is 1.0 % ionized.*

Weak Acids

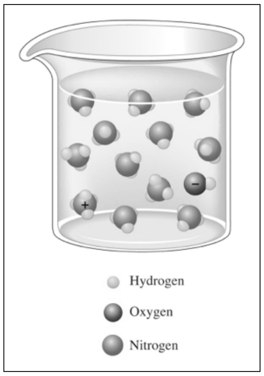
Percent Ionization



Strong bases such as sodium hydroxide are completely ionized



Weak bases such as NH_3 are only partially ionized



QUESTION #R.7

Which of the following is *not* a strong base?

A. $Ca(OH)_2$
B. KOH
C. CH_3NH_2
D. LiOH
E. $Sr(OH)_2$

QUESTION #R.8

Aniline, $C_6H_5NH_2$, was isolated in the 1800s and began immediate use in the dye industry. What would be the formula of the conjugate acid of this base?

A. $C_6H_5NH_2^+$
B. $C_6H_5NH_3^+$
C. $C_6H_5NH^-$
D. $C_6H_5NH^+$

QUESTION #R.9

Values of K_a for Some Common Monoprotic Acids

Formula	Name	Value of K_a*
HSO_4^-	Hydrogen sulfate ion	1.2×10^{-2}
$HClO_2$	Chlorous acid	1.2×10^{-2}
$HC_2H_2ClO_2$	Monochloracetic acid	1.35×10^{-3}
HF	Hydrofluoric acid	7.2×10^{-4}
HNO_2	Nitrous acid	4.0×10^{-4}
$HC_2H_3O_2$	Acetic acid	1.8×10^{-5}
$[Al(H_2O)_6]^{3+}$	Hydrated aluminum(III) ion	1.4×10^{-5}
HOCl	Hypochlorous acid	3.5×10^{-8}
HCN	Hydrocyanic acid	6.2×10^{-10}
NH_4^+	Ammonium ion	5.6×10^{-10}
HOC_6H_5	Phenol	1.6×10^{-10}

↑ Increasing acid strength

Use information on this table to determine which of the following bases would have the <u>weakest</u> conjugate acid:

$OC_6H_5^-$; $C_2H_3O_2^-$; OCl^-; NH_3

A. $OC_6H_5^-$
B. $C_2H_3O_2^-$
C. OCl^-
D. NH_3

The pH Scale

$pH \approx -log[H^+] \approx -log[H_3O^+]$

- *pH in water ranges from 0 to 14.*
- $K_w = [H^+][OH^-] \approx 1.00 \times 10^{-14}$
- ***pK_w = -log K_w, pH= -log $[H_3O^+]$, and pOH = -log$[OH^-]$***
- pK_w = ***pH + pOH ≈ 14.00***
- *As pH rises, pOH falls (sum = 14.00).*
- *There are no theoretical limits on the values of pH or pOH.* *(e.g. pH of 2.0* M *HCl is -0.301)*

The Relations Among $[H_3O^+]$, pH, $[OH^-]$, and pOH

		$[H_3O^+]$	pH	$[OH^-]$	pOH
MORE BASIC ↑	BASIC	1.0×10^{-15}	15.00	1.0×10^{1}	−1.00
		1.0×10^{-14}	14.00	1.0×10^{0}	0.00
		1.0×10^{-13}	13.00	1.0×10^{-1}	1.00
		1.0×10^{-12}	12.00	1.0×10^{-2}	2.00
		1.0×10^{-11}	11.00	1.0×10^{-3}	3.00
		1.0×10^{-10}	10.00	1.0×10^{-4}	4.00
		1.0×10^{-9}	9.00	1.0×10^{-5}	5.00
		1.0×10^{-8}	8.00	1.0×10^{-6}	6.00
	NEUTRAL	1.0×10^{-7}	7.00	1.0×10^{-7}	7.00
MORE ACIDIC ↓	ACIDIC	1.0×10^{-6}	6.00	1.0×10^{-8}	8.00
		1.0×10^{-5}	5.00	1.0×10^{-9}	9.00
		1.0×10^{-4}	4.00	1.0×10^{-10}	10.00
		1.0×10^{-3}	3.00	1.0×10^{-11}	11.00
		1.0×10^{-2}	2.00	1.0×10^{-12}	12.00
		1.0×10^{-1}	1.00	1.0×10^{-13}	13.00
		1.0×10^{0}	0.00	1.0×10^{-14}	14.00
		1.0×10^{1}	−1.00	1.0×10^{-15}	15.00

QUESTION #R.10

In an EPA pond water sample at 19.5 ºC, the [H^+] was instrumentally determined to be 1.2×10^{-6} M. What is the [OH^-] in the sample? Is the sample acidic, basic, or neutral?

A. 1.2×10^{-20} M; acidic
B. 1.2×10^{-20} M; basic
C. 8.3×10^{-9} M; basic
D. 8.3×10^{-9} M; acidic

Weak Acids

K_a and Calculating pH

- *Write the balanced chemical equation clearly showing the equilibrium.*
- *Write the equilibrium expression. Use the value for* K_a
- *Let* x = [H^+]; *substitute into the equilibrium constant expression and solve.*
- *Convert* [H^+] *to pH.*

K_a and Calculating pH

What is the pH value for a 0.100M solution of HF ($K_a = 3.53 \times 10^{-4}$)?

$$HF_{(aq)} \rightleftharpoons H^+_{(aq)} + F^-_{(aq)}$$

$$K_a = \frac{[H^+][F^-]}{[HF]}$$

Equilibrium Concentration Calculations

$$HF_{(aq)} \leftrightarrows H^+_{(aq)} + F^-_{(aq)}$$

Concentration (M)	HF	H^+	F^-
Initial	0.100	0	0
Change	0.100-x	+x	+x
Equilibrium	0.100-x	x	x

$$K_c = \frac{[H^+][F^-]}{[HF]} = 3.53 \times 10^{-4} = \frac{x^2}{(0.100 - x)}$$

$$3.53 \times 10^{-4} (0.100 - x) = x^2$$

Quadratic:

$$0 = x^2 + 3.53 \times 10^{-4} x - 3.53 \times 10^{-5}$$

x=[H^+] = 0.00805 M; pH= 2.09

Simplified:

$$3.53 \times 10^{-4} = \frac{x^2}{(0.100)}$$

$$3.53 \times 10^{-4} (0.100) = x^2$$

$$x = [3.53 \times 10^{-4} (0.100)]^{1/2}$$

x=[H^+] = 0.00594 M; pH= 2.23

QUESTION #R.11

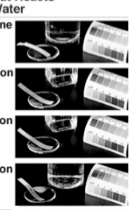
Butyric acid, $HC_4H_7O_2$, is a weak acid, which is foul smelling that can be found in spoiled butter. But, un-intuitively the compound has many uses in synthesizing many popular, common food flavors. The K_a of $HC_4H_7O_2$ at room temperature is 1.5×10^{-5}. What would be the pH of a 0.20 M solution of the acid?

A. 5.52
B. 4.82
C. 2.76
D. –0.70

Behavior of Salts in Water

The Behavior of Salts in Water

Salt Solution (Examples)	pH	Nature of Ions	Ion That Reacts with Water
Neutral [NaCl, KBr, $Ba(NO_3)_2$]	7.0	Cation of strong base; Anion of strong acid	None
Acidic [NH_4Cl, NH_4NO_3, CH_3NH_3Br]	<7.0	Cation of weak base; Anion of strong acid	Cation
Acidic [$Al(NO_3)_3$, $CrCl_3$, $FeBr_3$]	<7.0	Small, highly charged cation; Anion of strong acid	Cation
Basic [CH_3COONa, KF, Na_2CO_3]	>7.0	Cation of strong base; Anion of weak acid	Anion



$LiNO_2$ NH_4Cl $Ca(NO_3)_2$

The anions are the conjugate bases of the corresponding acids.

$MgSO_4$ $AgClO_3$ CsCN

QUESTION #R.12

The following salts were all placed in separate solutions at the same temperature so that their concentrations were all equal. Arrange them in order from lowest pH to highest pH.

NaCl; NH_4NO_3; $Ca(C_2H_3O_2)_2$; $AlCl_3$

Additional information: K_b for $NH_3 = 1.8 \times 10^{-5}$; K_a for $HC_2H_3O_2 = 1.8 \times 10^{-5}$; K_a for $Al(H_2O)^{3+} = 1.4 \times 10^{-5}$.

A. NaCl; NH_4NO_3; $Ca(C_2H_3O_2)_2$; $AlCl_3$
B. $AlCl_3$; NaCl; NH_4NO_3; $Ca(C_2H_3O_2)_2$
C. $AlCl_3$; NH_4NO_3; NaCl; $Ca(C_2H_3O_2)_2$
D. NH_4NO_3; $AlCl_3$; NaCl; $Ca(C_2H_3O_2)_2$

Oxides + H_2O

- *Acidic Oxides (Acid Anhydrides):*
- *O–X [Oxygen- nonmetal bond] is strong and covalent; **form acids** with water.*

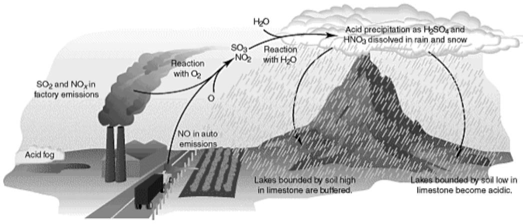
SO_2, NO_2, CrO_3 , CO_2

- *Basic Oxides (Basic Anhydrides):*
- *O–X [Oxygen- metal bond] bond is ionic, **form bases** with water.*

K_2O, CaO

A naturally occuring example is the phenomenon of acid rain.

Formation of Acid Rain



How does this relate to global warming and energy policy?

Fossil fuels: coal and oil?

Acid Rain

The pH of "clean" rain is slightly acidic ~5.6 due to the CO_2 - carbonic acid equilibrium:

$$CO_{2\,(g)} + H_2O_{(l)} \rightleftharpoons H_2CO_{3\,(aq)} \rightleftharpoons H_3O^+_{(aq)} + HCO_3^-{}_{(aq)}$$

Acids are produced by the reaction of sulfur dioxide and sulfur trioxide with water, which add to the acidity of rain.

$$SO_{2\,(g)} + H_2O_{(l)} \rightleftharpoons H_2SO_{3\,(aq)}$$

$$2\,SO_{2\,(g)} + O_{2\,(g)} \rightleftharpoons 2\,SO_{3\,(g)}$$

$$SO_{3\,(g)} + H_2O_{(l)} \rightleftharpoons H_2SO_{4\,(aq)}$$

QUESTION #R.13

An environmental chemist obtained a sample of rainwater near Buffalo, N.Y. The $[H^+]$ was determined to be 3.5×10^{-6} M. What is the pH, pOH, and $[OH^-]$ of the solution?

A. pH = 5.46 ; pOH = 8.54; $[OH^-] = 7.0 \times 10^{-6}$ M
B. pH = 5.46 ; pOH = 8.54; $[OH^-] = 2.9 \times 10^{-9}$ M
C. pH = 12.56 ; pOH =1.44 ; $[OH^-] = 3.6 \times 10^{-2}$ M
D. pH = 8.54; pOH = 5.46; $[OH^-] = 2.9 \times 10^{-9}$ M

pH, pK_w, pK_a, pK_b

- *pH = -log$[H^+]$ = -log$[H_3O^+]$*
- *pK_w **= pH + pOH ≈ 14.00***
- *pK_w = -log K_w, pK_a = -log K_a, and pK_b = -log K_b*
- *Also, $pK_w = pK_a + pK_b$*
- *pK_w **= pK_a + pK_b ≈ 14.00***

QUESTION #R.14

Two weak acids, HA and HB are placed in separate solutions so that their molarities are the same. Which, if either, would have the larger value for K_a if the pH of the HA solution were <u>lower</u> than the pH of the HB solution?

A. HA has the larger K_a.
B. HB has the larger K_a.
C. The K_a of HA = K_a of HB.
D. More information is needed to answer the question.

Aqueous Reactions

Aqueous Reactions & Solutions

- *Many reactions occur in a homogeneous liquid or gas phase which generally improves reaction rates.*
- *The prime medium for many inorganic reactions is water which serves as a solvent (the substance present in the larger amount), but does not react itself.*
- *The substance(s) dissolved in the solvent is (are) the solute(s). Together they comprise a solution. The reactants would be the solutes.*
- *Reaction solutions typically have less solute dissolved than is possible and are "unsaturated".*
- *There are many examples of aqueous reactions. As you saw in the naturally occuring example of acid rain.*

Types of Chemical Reactions

- *Combination (Synthesis)*
- *Decomposition*
- *Single Displacement*
- *Double Displacement (Metathesis:"Exchange Reactions)*
- *Combustion*
- *Others: Oxidation-Reduction, Neutralization,* ***Precipitation****,* ***Complexation***

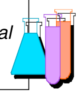
General Chemical Reactions

Double Displacement "Metathesis": "Exchange Reactions"

- *AB + CD $\longrightarrow$ AD + CB*
- *Example:*
  - *A solution of sodium phosphate reacts with a solution of silver nitrate to produce aqueous sodium nitrate and a precipitate of silver phosphate.*
  - *Balanced equation: ?*
  - *What is another description for this type of reaction?*

Aqueous Reactions

- In Chem 121 (Qualitative Analysis) there will be 4 important types:
  1) ***Acid-Base Reactions (Neutralization)*** *generally produces a salt plus water*
  2) ***Precipitation:*** *An insoluble salt forms from the addition of solutions.* ***(Refer to Solubility Rules)***
  3) ***Oxidation-Reduction (Redox)*** *there is a change in oxidation numbers between reactants and products*
  4) ***Complex Ion Formation:*** *a metal ion is weakly bonded to an anion or electron rich neutral species that are referred to as ligands (A special case: not a general reaction)*



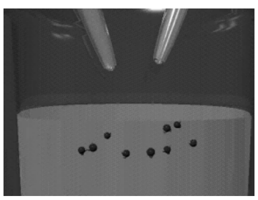
QUESTION #R.15

Some CO_2 gas is bubbled into water. Which of the following compounds would be suitable to now neutralize the CO_2 infused solution?

A. K_2O
B. NaCl
C. NH_4Br
D. $AlCl_3$

Aqueous Reactions: Neutralization

Workshop: Ions in Solution



Aqueous Reactions: Neutralization

Net Ionic Equations

$$HCl_{(aq)} + NaOH_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$$

- $HCl_{(aq)} \rightarrow H^+_{(aq)} + Cl^-_{(aq)}$
- $NaOH_{(aq)} \rightarrow Na^+_{(aq)} + OH^-_{(aq)}$
- $NaCl_{(aq)} \rightarrow Na^+_{(aq)} + Cl^-_{(aq)}$

$$Na^+_{(aq)} + OH^-_{(aq)} + H^+_{(aq)} + Cl^-_{(aq)} \rightarrow Na^+_{(aq)} + Cl^-_{(aq)} + H_2O_{(l)}$$

$$H^+_{(aq)} + OH^-_{(aq)} \rightarrow H_2O_{(l)}$$

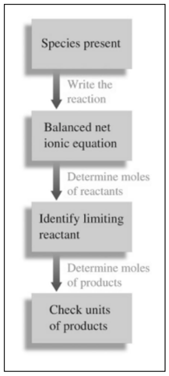
QUESTION #R.16

In the balanced molecular equation for the neutralization of sodium hydroxide with sulfuric acid, the products are:

A) $NaSO_4 + H_2O$
B) $Na_2SO_4 + 2H_2O$
C) $2NaSO_4 + H_2O$
D) $Na_2S + 2H_2O$

Aqueous Reactions (Calculations)

Neutralization Reactions: Calculation Scheme



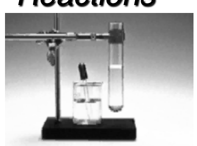
QUESTION #R.17

What is the molarity of a sodium hydroxide solution if 25.0 mL of this solution reacts exactly with 22.30 mL of 0.253 M sulfuric acid?

A) 0.113 M
B) 0.226 M
C) 0.284 M
D) 0.451 M

The Reaction of $Pb(NO_3)_2$ and NaI

Precipitation Reactions



Question #R.18

Identify the products by name.

A. Lead nitrite and sodium iodide
B. Lead iodide and sodium nitrate
C. Lead (IV) iodide and sodium nitrite
D. Lead (II) iodide and sodium nitrate

Solubility Guidelines for Common Ionic Compounds in Water

Soluble Ionic Compounds		Important Exceptions
Compounds containing	NO_3^-	None
	$C_2H_3O_2^-$	None
	Cl^-	Compounds of Ag^+, Hg_2^{2+}, and Pb^{2+}
	Br^-	Compounds of Ag^+, Hg_2^{2+}, and Pb^{2+}
	I^-	Compounds of Ag^+, Hg_2^{2+}, and Pb^{2+}
	SO_4^{2-}	Compounds of Sr^{2+}, Ba^{2+}, Hg_2^{2+}, and Pb^{2+}
Insoluble Ionic Compounds		**Important Exceptions**
Compounds containing	S^{2-}	Compounds of NH_4^+, the alkali metal cations, and Ca^{2+}, Sr^{2+}, and Ba^{2+}
	CO_3^{2-}	Compounds of NH_4^+ and the alkali metal cations
	PO_4^{3-}	Compounds of NH_4^+ and the alkali metal cations
	OH^-	Compounds of the alkali metal cations, and Ca^{2+}, Sr^{2+}, and Ba^{2+}

Aqueous Reactions: Precipitation

Net Ionic Equations

- ***100mL of a 0.1M solution of sodium sulfate is mixed with 100mL of a 0.1M solution of silver nitrate. What are the resulting concentrations of silver ion and sodium ion respectively in the product solution?***
- *Molecular Equation:*

Aqueous Reactions: Precipitation

Ionic Equation: REACTANTS

Aqueous Reactions: Precipitation

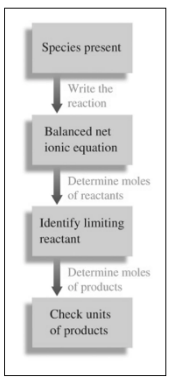
Ionic Equation: PRODUCTS

Aqueous Reactions: Precipitation

Net Ionic Equation

Concentration of silver ion?
Concentration of sodium ion?

Determining the Mass of Product Formed



Solution Applications

20.00 *mL of a 0.01M barium chloride solution required* ***15.50*** *mL of the potassium sulfate solution to react completely.* $\boldsymbol{M_{K2SO4}}$ ***= ?***

Solution Applications

How many grams of potassium chloride are produced?

Solution Applications

If ***20.00*** *mL of a* ***0.10*** *M solution of barium chloride were reacted with* ***15.00*** *mL of a* ***0.20*** *M solution of potassium sulfate, what would be the theoretical yield of barium sulfate?*

Must use the limiting reagent:

Which is the Limiting Reagent?

Solution Applications

*If **20.00** mL of a **0.10** M solution of barium chloride was reacted with **15.00** mL of a **0.20** M solution of potassium sulfate, what would be the theoretical yield of barium sulfate?*

Must use the limiting reagent:

Aqueous Reactions

- *In Chem 121 (Qualitative Analysis) there will be 4 important types: Acid-Base, Precipitation, Complexation, and Oxidation-Reduction*
- ***The last two reaction types will be addressed in detail later.***

  *3) **Oxidation-Reduction (Redox)** there is a change in oxidation numbers between reactants and products (**Chapter on Electrochemistry**)*

  *4) **Complex Ion Formation:** a metal ion is weakly bonded to an anion or electron rich neutral species that are referred to as ligands. (**Chapter on the Chemistry of Coordination Compounds**)*