Unit #7, Chapter 8 Outline
Acids, Bases and pH

Lesson	Topics Covered	Homework Questions and Assignments
1&2	**Review of Acids from Grade 11** • Arrhenius acids and bases, definition • chemical properties of acids & bases • naming acids and bases **Strong and weak acids**: • definitions and properties • memorize the common strong acids: HCl, HBr, HI, H_2SO_4, HNO_3, $HClO_3$, ($HClO_4$) **Strong and weak bases**: • definitions and properties • memorize the strong bases: oxides & hydroxides and oxides of Group I and Group II metals (except Be)	1. For a review of naming acids, read page 596 2. Read pages: 376 –377 and 383 – 384 3. Complete **<u>Handout</u>**: Naming Common Acids and Bases and Reaction of Acids and Bases (answers on internet)
2	**Introduction to pH and Strong Acids** • [H_3O+] of acids depends on **<u>both</u>** the strength and the concentration of the acid • pH = – log [H_3O^+] For ALL strong acids: [H_3O+] = [acid] • strong acids completely ionize in water • for H_2SO_4, only the first ionization is complete, so H_2SO_4 behaves the same as a monoprotic acid in water Calculate the pH of solutions made by diluting stock solutions ($C_1V_1 = C_2V_2$)	Calculate the pH of the following solutions: a) 3.00 HI (aq) b) 5.00 M H_2SO_4 (aq) c) 25 mL of 15.0 M HNO_3 stock solution diluted to 1.0 L of solution d) 500.0 mL of 6.00 H_2SO_4 solution diluted to 3.00 L of solution **Quick Answers: (full answers on website, in Calculations Involving Strong Acids and Bases, full answers)** a) pH = – 0.477 (3 decimal places) b) [H_3O+] = [H_2SO_4] = 5.00M; then pH = – 0.699 c) [H_3O+] = [HNO_3] = 0.375M; then pH = 0.43 d) [H_3O+] = [H_2SO_4] = 1.00M; then pH = 0.00
3	**Introduction to pOH and Strong Bases** • [OH^{1-}] of bases depends on **<u>both</u>** the strength and the concentration of the base • pOH = – log [OH^{1-}] • pH + pOH = 14 Strong bases completely dissociate in water: • for strong bases with one hydroxide group, the [OH^-] = [base] • for strong bases with two hydroxide groups, the [OH^-] = 2 x [base] Calculate the pH of solutions made by dissolving solid bases in water (n = m/MM and C = n/V)	1. Read pages 390 - 392 2. On page 392, do Q 13 - 18 3. Complete **<u>Handout</u>** given out in class: Introduction to pH and pOH (*look for the patterns) 4. Calculate the pH of the following solutions: a) 0.025 M LiOH (aq) b) 0.060 M $Ba(OH)_2$ (aq) c) 3.66 g of NaOH dissolved in 400.0 mL water d) 8.55 g of $Mg(OH)_2$ dissolved in 2.00 L water e) 2.50 g of CaO (s) dissolved in 500.0 mL water **Full answers on website, in Calculations Involving Strong Acids and Bases, full answers)**
4	**Bronsted-Lowry Acids and Bases** • definitions • ionization reactions with water • conjugate acid-base pairs • weak acids and bases form equilibrium mixtures of conjugate acid/base pairs • water can be an acid or a base, so it is "amphoteric" (aka "amphiprotic")	1. Read pages 380 – 382 2. On page 382, do Q 1 – 4 (answers on page 417 are correct)

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<table>
<tr><th>Lesson</th><th>Topics Covered</th><th>Homework Questions and Assignments</th></tr>
<tr><td>5</td><td>Weak Acids and Bases
• Ka and Kb
• writing Ka and Kb reactions and expressions
• the self-ionization of water and Kw
• $[H_3O^+] \times [OH^-] = 1.0 \times 10^{-14}$
• Ka x Kb = Kw</td><td>1. Do homework on <u>Handout</u>: Working with Ka, Kb and Kw, including:
2. On page 387, do Q 1 – 5
3. Read pages 388 – 390
4. On page 390, do Q 9 – 12

Answers to handout questions on internet</td></tr>
<tr><td>6 & 7</td><td>Calculations Involving Ka and Kb of Weak Acids and Bases
• using Ka or Kb to calculate pH (ICE tables)
• % dissociation
• using pH or pOH to calculate Ka or Kb
• 500s rule</td><td>1. Read pages 396 – 403
2. On page 400, Q 19 – 24 (Hint for Q24, let x = the initial concentration of acid. There are full solutions posted on the internet)
3. On page 402, Q 25 – 28 (Hint for Q25, to find $[CO_3^{2-}]$ use the second Ka. The answer for Q25 is posted on the internet.)
4. On page 407 Q 29 – 34</td></tr>
<tr><td>8</td><td>The pH of salt solutions
• hydrolysis reactions
• salts with strong parent acid and strong parent base are neutral
• salts with strong parent acid and weak parent base are acidic
• salts with weak parent acid and strong parent base are basic

Summary: pH of Aqueous Solutions</td><td>1. Complete <u>Handout</u>: The pH of Salt Solutions
2. Begin Review for Quiz on Acids, Bases and Salts(material from lessons 1- 8). Review on internet. Quiz on: ______________________</td></tr>
<tr><td>9</td><td>Introduction to Acid-Base Titrations
• chemical indicators and how to select
• measuring the solution to be analyzed using a pipette
• performing the titration using a burette
• calculating the concentration of the unknown</td><td>1. Work on Review for Quiz on Acids, Bases and Salts (up to the end of lesson 8).</td></tr>
<tr><td>10</td><td>Titration Calculations
• CaVa = CbVb
• accounting for mole ratios
• standardizing acid or base solutions
• primary standards</td><td>1. Do questions on Handout: Titration Calculations (you need this theory for Lab 9)
2. Read through Lab 9: Acid-Base Titrations. Prepare your observation chart(s).</td></tr>
<tr><td>11 & 12</td><td>Lab 9: Acid-Base Titrations
• this is a summative lab (5% of final mark)
• pre-lab demonstration of pipette and burette techniques
• standardize the NaOH solution
• titrations of weak acid(s)</td><td>1. Begin calculations for lab 9 by calculating the concentration of the sodium hydroxide solution.
2. Use the concentration of standardized sodium hydroxide to complete the titration calculations for the weak acid(s).
3. Write up lab report, due at the beginning of lesson on _________________________ .
4. Work on titration calculations. You will on the pH of salt solutions and titrations on the next Unit test.</td></tr>
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Unit 7, Lesson 01: Review of Acids and Bases

	Acids	Bases
Arrhenius Definition		
How to recognize from a chemical formula		
Examples		
Which ion gives them their properties?		
Are they electrolytes?		
Taste		
Skin feel		
Colour with phenolphthalein (phth)		
Colour with red or blue litmus paper		
Colour with bromothymol blue		
Reaction with metals		
Reaction with carbonates		
pH		

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

Writing the reactions of acids with metals to produce hydrogen gas and a salt:

$Li\ (s) \quad + \quad H_2SO_4\ (aq) \quad \rightarrow$

$Zn\ (s) \quad + \quad HNO_3\ (aq) \quad \rightarrow$

Writing the reactions of acids with carbonates to produce carbon dioxide, water and a salt:

$HBr\ (aq) \quad + \quad Na_2CO_3\ (s) \quad \rightarrow$

$HClO_3\ (aq) \quad + \quad CaCO_3\ (s) \quad \rightarrow$

Naming Acids

Acids are written with hydrogen as their first element.

The name of the acid depends on the name of its negative ion.

The following are the naming rules:

- if the name of the ion ends in "ide", name the acid ________________________________
- if the name of the ion ends in "ate", change the "ate" suffix to ______________________
- if the name of the ion ends in "ite", change the "ite" suffix to _______________________

Formula of Acid	Name of the Ion	Name of the Acid
HCl		
$HClO_3$		
H_2SO_3		
HIO_4		
HI		
		nitrous acid
HCN		
		hydrosulfuric acid
		chromic acid

Strength of Acids and Bases

Acids and bases are described in terms of their concentration and their strength.

1. **Concentration** indicates how much acid or base is dissolved in a certain amount of solution

eg. 5.0% V/V acetic acid: ____

eg. 3.0 M HCH_3COO (aq): ____

eg. 0.010 M HCl: ____

eg. 6.0 M NaOH: ____

2. **Strength** indicates how much the acid or base ___________________ to form ________ in solution

Strong Acids:

- completely ________________ into ions in solution; essentially all of the acid is converted to ______
- are ___________________ electrolytes in solution
- pH is ___________________ (close to ____ or _____)

There are only 6 **common** strong acids (you must memorize them):

____ ___________________________________

____ ___________________________________

____ ___________________________________

Dissociation reactions (go to completion so use a → arrow)

HCl (g)

HNO_3 (l)

Trends in acid strength:

- acid strength increases down a group on the periodic table eg. _______< _______< _______<_______
- acid strength increases across a period (→) eg. _________< __________< ____________
- acid strength increases as the # of oxygen atoms increases eg. _________<__________< _________

Weak Acids:

- less than 1% of the acid molecules ___________________ (separate) into ions in solution
- almost all of the acid is found in solution as ________________________ with the H^+ ion still attached
- are _____________________ electrolytes in solution
- pH is between _______ and about _______
- if an acid is NOT one of the six strong acids, then it is a _________________

eg. HNO_2 (l)

eg. HCH_3COO (l)

Strong Bases:

- completely _______________ into ions in solution; essentially all of the base is converted to ______
- are _____________________ electrolytes in solution
- pH is __________________ (close to ____ or _____)

The strong bases are: (memorize them)

- the oxides and hydroxides of the Group I metals: _______________________________________
- the oxides and hydroxides of the Group II metals (except _____): __________________________ __________________________

eg. NaOH

eg. CaO

Weak Bases:

- less than 1% of the molecules ___________________ into ions in solution
- almost all of the base is found in solution as ________________________ with the OH^- still attached
- many weak bases are ____________________ in water
- are _____________________ electrolytes in solution
- pH is between _______ and about _______
- if a base is NOT one of the strong bases, then it is a _________________

eg. $Sc(OH)_3$

eg. $Pb(OH)_4$

Unit 7, Lesson 01: Naming Common Acids and Bases

1. Name the following acids and classify them as either strong or weak acids.

Formula	Name	Strong or Weak Acid
H_2CO_3		
H_3PO_4		
H_2S		
H_2SO_4		
HNO_3		
HBr		
HF		
HI		
$H_2C_2O_4$		
H_2SO_3		
HNO_2		
HIO		
$HClO_3$		
$HBrO_3$		
$HClO_4$		
HCH_3COO		
HClO		

2. Name the following bases and classify them as either strong or weak bases. Use Roman numerals where needed.

NaOH		
ZnO		
$Ca(OH)_2$		
$Fe(OH)_3$		
$Mg(OH)_2$		
$Al(OH)_3$		
BaO		
KOH		
AgOH		
CdO		
Li_2O		
$Sn(OH)_4$		
LiOH		
NH_4OH		
K_2O		
Ni_2O_3		
$Ba(OH)_2$		

Unit 7, Lesson 01: Reactions of Acids and Bases

1. Write **balanced** chemical equations to show the dissociation of the following substances in water. For the strong acids and bases, they dissociate completely so use a "→" arrow. For the weak acids and bases, they do NOT dissociate completely so use a "↔" arrow.

$HC_2H_3O_2$ (l)

$Cd(OH)_2$ (s)

$HClO_4$ (l)

MgO (s)

H_2CrO_4 (aq)

$Al(OH)_3$ (s)

Li_2O (s)

2. Write **balanced** chemical equations for the reactions between the following substances. Be sure that you can name all of the compounds from these equations. Assume that these reactions go to completion and that the salts dissolve in water.

HCl (aq) + Li (s) →

HNO_3 (aq) + Mg (s) →

$HClO_4$ (aq) + K_2CO_3 (aq) →

H_2SO_4 (aq) + $CaCO_3$ (s) →

HBr (aq) + Co (s) →

H_2SO_3 (aq) + $MgCO_3$ (s) →

nitrous acid + zinc metal

hypobromous acid and aluminum metal

phosphoric acid and sodium carbonate

hydrosulfuric acid and sodium metal

Unit 7, Lesson 05: Working with Ka, Kb and Kw

1. On page 387, do Q 1 – 5
2. Read pages 388 – 390
3. On page 390, do Q 9 – 12
4. For each of the following acids:

- write the ionization reaction in water and the Ka expression
- write the ionization reaction for its conjugate base and Kb expression
- calculate the value of Kb for the conjugate base

a) benzoic acid
b) hydrofluoric acid
c) iodic acid
d) $H_2BO_3^{1-}$ (aq)
e) HCO_3^{1-} (aq

5. For each of the following bases:

- write the ionization reaction in water and the Kb expression
- write the ionization reaction for its conjugate acid and Ka expression
- calculate the value of Ka for the conjugate acid

a) hydroxlamine
b) ethanamine
c) urea
d) $H_2BO_3^{1-}$ (aq)
e) HCO_3^{1-} (aq)

6. Given the relationship $K_a \cdot K_b = K_w$, complete the following statements:

a) If the K_a for an acid is large, the K_b for its conjugate base is: ________________
b) If the K_a for an acid is small, the K_b for its conjugate base is: ________________
c) If the K_b for a base is large, the K_a for its conjugate acid is: ________________
d) If the K_b for a base is small, the K_a for its conjugate acid is: ________________

Unit 7, Lesson 08: The pH of Salt Solutions

1. Complete the following chart:

Ion	Parent Acid or Base	Is the parent strong or weak?	Will this ion hydrolyze?	If the ion will hydrolyze (react with water), write the ionization reaction. If not, write "no reaction" or NR.	pH of ion in solution (acidic, basic or neutral)
NH_4^{1+}					
PO_3^{3-}					
Na^{1+}					
$N_2H_5^{1+}$					
HCO_3^{1-}					
SO_4^{2-}					
Ca^{2+}					
NO_3^{1-}					

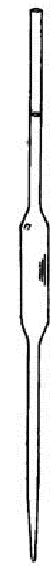
2. For each of the following salts:
- identify its parent acid and parent base and indicate if they are strong or weak
- for the ions which will react with water (hydrolyze) in solution, write the hydrolysis reaction
- state whether the salt solution is acidic, basic or neutral

a) sodium nitrate
b) ammonium chloride
c) lithium oxalate
d) silver bromide
e) magnesium fluoride
f) potassium hydrogen carbonate
g) barium hydrogen phosphate
h) strontium sulfate
i) calcium oxide
j) $(N_2H_5)ClO_4$

3. Calculate the pH of the following salt solutions. You will need to write dissociation equations and use ICE tables. Full answers on internet.

a) 1.60 M solution of NH_4Cl
b) 0.0155 M solution of $NaHCO_3$
c) 0.750 M solution of KNO_2
d) 0.335 M solution of $(N_2H_5)ClO_3$

Unit 7, Lesson 09: Acid – Base Titrations



<u>Titration</u> is an analytical method which can be used to determine the concentration of a solution. Titration which involve neutralization reactions and can be used to determine the concentration of a solution of an acid or base.

Step 1: Select an indicator

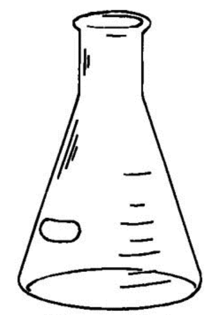
- a chemical indicator is a weak acid or base that ________________________ at a certain pH
- the pH at which the chemical indicator changes colour is called the __________________
- the endpoints of common indicators are shown on page 425

eg. phenolphthalein (phth) changes from colourless to pink at pH = _________
methyl red changes from red to yellow at pH = ________
bromocresol green changes from yellow to blue at pH = _________
alizarin changes from red to yellow at pH = _________

a) If a strong acid is being used to titrate a strong base:
- the salt will be __________, so select an indicator with endpoint close to ______

b) If a strong acid is being used to titrate a weak base:
- the salt will be __________, so select an indicator with endpoint ______

c) If a strong base is being used to titrate a weak acid:
- the salt will be __________, so select an indicator with endpoint ______



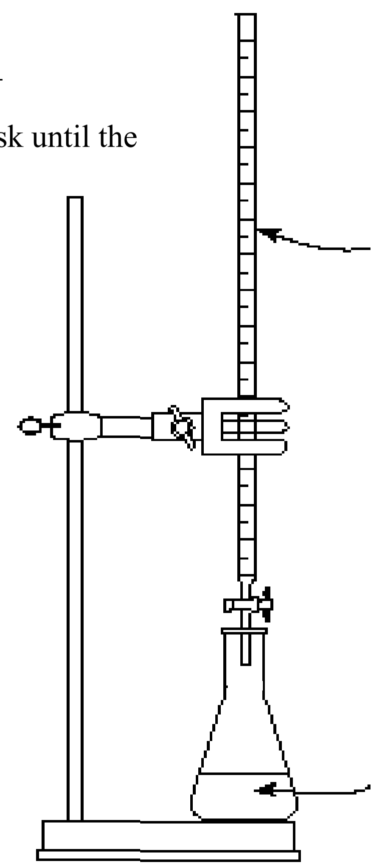
Erlenmeyer Flask

Step 2: Measure the volume of the solution to be analyzed

- an exact volume of the solution to be analyzed is measured using a ______________ and transferred to an _______________________________
- add about _____________ of the chemical indicator that was selected in Step 1

Step 3: Perform the titration

- an acid or base of known concentration is placed in a _______________
- this solution is called the _____________
- swirling constantly, the titrant is slowly added to the solution in the flask until the _______________ is reached and the indicator just changes colour
- if the chemical indicator has been chosen correctly, at the endpoint, the moles of acid ___________ the moles of base
- when moles of acid equals moles of base, it is called the ______________________________
- the volume of titrant added is read from the burette



Step 4: Calculate the concentration of the unknown solution

- the concentration of the titrant is known
- the volume of the titrant is measured from the ________________
- the volume of the unknown is measured from the ________________
- at the _____________________________, the moles of acid (H_3O^+) equals the moles of base (OH^-), so:

Unit 7, Lesson 10: Titration Calculations

Standardizing the Titrant Solution

To perform an accurate titration, the concentration of the titrant must be precisely and accurately known, so the titrant must be standardized before it can be used.

To determine the exact concentration of the titrant, it is titrated against a "**primary standard**". A primary standard is a solid acid or base that can be weighed out accurately. To be acceptable as a primary standard, the substance should:

1. be available as a very pure solid at a reasonable cost;
2. not react with any component of the air, such as oxygen, carbon dioxide or water vapour;
3. be stable in solution for a reasonable length of time; and
4. have a high molar mass to minimize weighing errors.

The solid primary standard weighed then dissolved in distilled water, and titrated to the endpoint with the titrant solution. If the indicator has been chosen correctly, it will change colour at the equivalent point, when the moles of primary standard is exactly equal to the moles of titrant. The concentration of the titrant can then be calculated using the number of moles and volume of the titrant.

Sample Calculation, Standardizing a Base Titrant Solution

A teacher prepares a 0.1 M solution of NaOH. To standardize this solution, she weighs out 0.380 g of the primary standard potassium hydrogen phthalate ($KHC_8H_4O_4$ which is abbreviated KHPh or KHP) and then dissolves it in distilled water. Phenolphthalein (phth) is added as an indicator. The primary standard is titrated with 19.20 mL of the NaOH solution. Calculate the exact concentration of the NaOH solution.

At the equivalence point (indicated by the endpoint), the moles of NaOH is equal to the number of moles of $KHC_8H_4O_4$. Find the moles of $KHC_8H_4O_4$:

n = mass / MM
  = 0.380 g / 204.23 g/mol
  = 0.0018606 mol $KHC_8H_4O_4$

At the equivalence point, the moles of acid (KHPh) = mole NaOH
Therefore, there are 0.0018606 moles NaOH in the 19.20 mL used. Find the molar concentration of NaOH:

C_{NaOH} = n / V
  = 0.0018606 mol / 0.01920 L
  = 0.0969 mol/L NaOH (to 3 sig digs)

Therefore, the concentration of the titrant NaOH is exactly 0.0969 mol/L (3 sig digs).

To standardize the NaOH, do at least three titrations against the primary standard. When you have three results that are very close, take the average of these three results as the concentration of the titrant.

In preparation for the Titration lab, read pages 600 – 601 in your text book.

Unit 7, Lesson 10: Titration Calculations

1. Define: titration, primary standard, standardization, equivalence point, endpoint, pipette and burette.

2. The following acid solutions were titrated with 0.150 mol/L sodium hydroxide. Write the neutralization equation for each reaction and calculate the concentrations of the acid solutions.
   a) 25.00 mL of HCl requiring 16.50 mL of base solution (0.0990 M)
   b) 25.00 mL of sulfuric acid solution requiring 42.00 mL of base solution (0.126 M)
   c) 10.00 mL of vinegar, containing acetic acid, CH_3COOH requiring 55.0 mL of base solution (0.825 M)

3. What volume of 0.350 M ammonium hydroxide will be required to titrate 50.0 mL of 0.275 M HCl? The reaction is:

   $NH_4OH\,(aq) + HCl\,(aq) \rightarrow H_2O\,(l) + NH_4Cl\,(aq)$ (39.3 mL)

4. A solution of HNO_3 of unknown concentration was titrated with 0.948 M KOH. 21.32 mL of the base was required to neutralize a 10.0 mL sample of acid. Find the concentration of the acid. The reaction is:

   $HNO_3\,(aq) + KOH\,(aq) \rightarrow H_2O\,(l) + KNO_3\,(aq)$ (2.02M)

5. 25.8 mL of 0.328 M sodium hydroxide solution are required to titrate 50.0 mL of sulfuric acid. Calculate the concentration of the acid. The reaction is:

   $2\,NaOH\,(aq) + H_2SO_4\,(aq) \rightarrow 2\,H_2O\,(l) + Na_2SO_4\,(aq)$ (0.0846M)

6. 50.0 g of solid NaOH are dissolved in 2.00 L of water. In a titration, a 25.0 mL sample of this solution exactly neutralizes 32.6 mL of hydrochloric acid. What is the concentration of the acid? The reaction is:

   $NaOH\,(aq) + HCl\,(aq) \rightarrow H_2O\,(l) + NaCl\,(aq)$ (0.479M)

7. A sample of powdered vitamin C (ascorbic acid, $HC_6H_7O_6$) is dissolved in water and titrated with a 0.150 M solution of sodium hydroxide. A total of 21.50 mL of base solution was required to change the colour of the indicator. How many grams of ascorbic acid did the tablet contain, assuming the presence of one acidic hydrogen atom per molecule? The reaction can be written:

   $NaOH\,(aq) + HC_6H_7O_6\,(s) \rightarrow H_2O\,(l) + NaC_6H_7O_6\,(aq)$ (0.568 g or 568 mg)

8. The compound acetylsalicylic acid (ASA), $HC_9H_7O_4$, is found in many pain relievers, such as Aspirin. An ASA product was analyzed by dissolving a tablet weighing 0.250 g in water and titrating with 0.030 M KOH. The titration required 29.40 mL of base. What was the percentage by weight of acetylsalicylic acid in the tablet?

   $KOH\,(aq) + HC_9H_7O_4\,(aq) \rightarrow H_2O\,(l) + KC_9H_7O_4\,(aq)$ (63.6%)

9. Maleic acid is a solid, diprotic acid with the chemical formula $H_2C_4O_4$. It was used to standardize a sodium hydroxide solution. It required 32.1 mL of the base to titrate 0.187 g of maleic acid. What is the concentration of the base?

   $2\,NaOH\,(aq) + H_2C_4O_4\,(s) \rightarrow 2\,H_2O\,(l) + Na_2C_4O_4\,(aq)$ (0.102 M)