Hourly I (March 17)

Review Notes

- Posted on CTools and course website

Review Sessions

- Friday, March 13, 6 - 8 pm, 1210 chem.
  - 6-6:40 am: Experiment 1
  - 6:40 - 7:20 am: Experiment 2
  - 7:20 - 8: Experiment 3
- Monday, March 15, 5:30 - 7:30 pm, 1800 chem.
  - Question and answers

E4 Acids, Bases, and Salts
March 12 - 17

Session two:

- Complete E4, Parts 3 - 5.
- Complete the team report and discussion presentation.

Acid - Base Neutralization (Parts 3 - 5)

Neutralization:

HNO_3 + NaOH → $NaNO_3$ + HOH

acid + base → salt + water

- The reaction of an acid with a base to produce salt and water

Acid - Base Neutralization

$HCl(g) + NH_3(g) \rightarrow NH_4Cl(s)$

acid base salt

DEMO

Neutralization Reaction Stoichiometry

- Neutralization reaction stoichiometry is dependant on the number of ionizable protons.

HNO_3 + NaOH → $NaNO_3$ + HOH

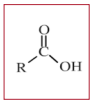
1 mol **1 mol**

H_2SO_4 + 2 NaOH → Na_2SO_4 + 2 HOH

1 mol **2 mol**

Carboxylic Acids (Parts 3 - 5)

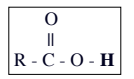
Carboxylic acids

C-based weak acids containing the  **group**

Carboxylic Acids and Ionizable Protons

Electronegativity of the elements*

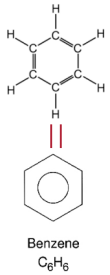
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
IA	IIA	IIIB	IVB	VB	VIB	VIIB		VIIIB		IB	IIB	IIIA	IVA	VA	VIA	VIIA
H 2.1																
Li **1.0**	Be 1.5											**B** **2.0**	**C** **2.5**	**N** **3.0**	O 3.5	F 4.0
Na **0.9**	**Mg** **1.2**											Al 1.5	Si 1.8	**P** **2.1**	**S** **2.5**	**Cl** **3.0**
K **0.8**	**Ca** **1.0**	Sc 1.3	Ti 1.5	V 1.6	Cr 1.6	Mn 1.5	Fe 1.8	Co 1.8	Ni 1.8	Cu 1.9	Zn 1.6	Ga 1.6	Ge 1.8	As 2.0	**Se** **2.4**	Br 2.8
Rb 0.8	Sr 1.0	Y 1.2	Zr 1.4	Nb 1.6	Mo 1.8	Tc 1.9	Ru 2.2	Rh 2.2	Pd 2.2	Ag 1.9	Cd 1.7	In 1.7	Sn 1.8	Sb 1.9	Te 2.1	I 2.5
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At



Carboxylic acid group

- **The electronegativity of H and O differ and therefore H in the COOH group is ionizable.**
- **The electronegativity of H and C are similar and therefore C-H bonds are stable and H in the C-H bond is NOT ionizable**

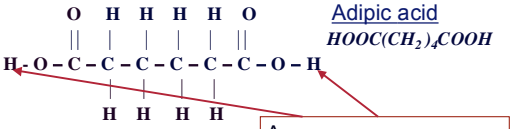
Q. How many ionizable protons does benzene (C_6H_6) contain?



Benzene C_6H_6

Answer
- No ionizable protons.
- Not an acid.

Q. How many ionizable protons does adipic acid contain?



Adipic acid
$HOOC(CH_2)_4COOH$

Answer:
Two ionizable protons.

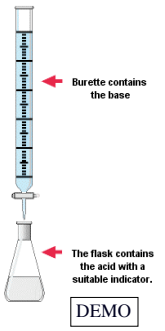
Acid-Base Neutralization

$CH_3COOH + NaOH \longrightarrow CH_3COONa + HOH$

acid base salt water

- Adding base to the weak carboxylic acid drives the reaction (donation of proton/s) to completion

Titration (Parts 3 -5)



DEMO

Base delivered from buret

Indicator color change signals the end-point or neutralization

Titration Stoichiometry

- Reaction stoichiometry is dependant on the number of ionizable protons in the carboxylic acid.

Acetic acid (Part 3):

$CH_3COOH + NaOH \rightarrow CH_3COONa + HOH$

1 mol **1 mol**

Oxalic acid (Part 4):

$HOOC\text{-}COOH + 2\ NaOH \rightarrow 2COONa + 2HOH$

1 mol **2 mol**

Q. How many mL of 0.10 M NaOH will be required to neutralize 10.0 mL of 0.10 M acetic acid?

Acetic acid

$CH_3COOH + NaOH \rightarrow CH_3OONa + HOH$

- 1 mol of NaOH is required to neutralize one mol of acetic acid:

1 mmol acid = 1 mmol base

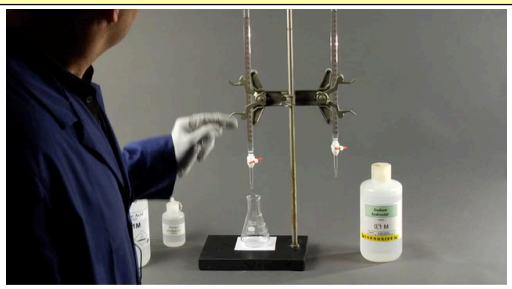
10.0 mL • 0.10 M acid = x mL • 0.10 M base

= 10 mL of 0.10 M NaOH

Watch the titration of 10.0 mL of 0.10 M acetic acid with 0.10 M NaOH

Note:
Look for an error!

Titration (Parts 3 -5)



$CH_3COOH + NaOH \rightarrow CH_3COONa + HOH$

Reaction monitored with phenolphthalein indicator

Part 3 Acid-Base Neutralizations and Indicators

- Compare the use of indicators for monitoring the neutralization of acetic acid with sodium hydroxide

Experiment variable
- Indicators

Experiment constants
- Acid identity, concentration, and volume
- Base identity and concentration

Indicator End Point pH

- The pH interval where the indicator changes color

colorless | pink

Phenolphthalein: pH 8.2 - pH 10.1

↑

pH 9.1

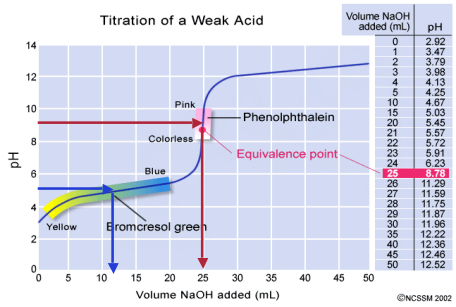
yellow | blue

Bromocresol green: pH 3.8 - pH 5.4

↑

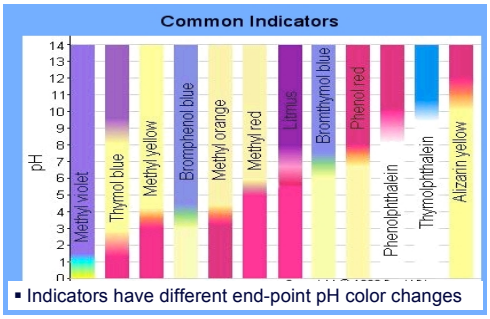
pH 4.6

Titration and Indicator pH End Points



Volume NaOH added (mL)	pH
0	2.92
1	3.47
2	3.79
3	3.98
4	4.13
5	4.25
10	4.67
15	5.03
20	5.45
21	5.57
22	5.72
23	5.91
24	6.23
25	8.18
26	11.29
27	11.59
28	11.75
29	11.87
30	11.96
35	12.22
40	12.36
45	12.46
50	12.52

Indicator pH End Points



- Indicators have different end-point pH color changes

- For information on lab indicators, see the lab manual, p. 194

Equivalence Point pH

- **The pH of the salt and water products** of the neutralization reaction = the equivalence point pH.
- The products may be acidic, or basic or neutral

Example:

$CH_3COOH + NaOH \rightarrow CH_3COONa + HOH$

Equivalence point pH ≈ pH 8

DEMO

Acid-Base Neutralization Products

Acetic acid + NaOH ⟶ sodium acetate + HOH

•The salt and water product is not neutral

DEMO

Parts 4-5: Equivalent Weight (EW) of an Acid

- Mass (grams) of compound providing one mole of H^+

or = Molecular weight / # ionizable protons

Examples:

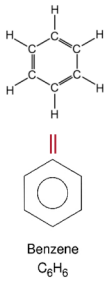
H_2SO_4 = molecular weight = 98

H_2SO_4 = equivalent weight = 49

HCl = molecular weight = 36.5

HCl = equivalent weight = 36.5

Q. Themolecular weight of benzoic acid = 122. What is its equivalent weight?



Benzene C_6H_6

Benzoic acid

Benzoic acid = C_6H_5COOH

Answer:

EW = 122

Q. An acid has an equivalent weight (EW) of 88.92 g/mole. List the number of any compound from the table that may be the acid.

Compound	Formula	MW
1. Ethanoic acid	CH_3COOH	60
2. Butanoic acid	$CH_3CH_2CH_2COOH$	88
3. Oxalic acid	HOOC-COOH	90
4. 1-methyl, 1,2 benzene dicarboxylic acid	$CH_3C_6H_3(COOH)_2$	180

Answer. Compounds # 2 and # 4.

A teammate titrates a carboxylic acid and calculates the EW of the acid to be 72.50g/mol. The result is correct within 2%. The MW of the acid = 1.5×10^2

Circle each structure that is consistent with the data.

Adipic Acid, MW = 146:
$HO_2CCH_2CH_2CH_2CH_2CO_2H$

Trans-cinnamic acid, MW=148

-CH=CH-COOH

Citric Acid, MW = 192:
$HO_2C\text{-}CH_2\text{-}C(OH)(CO_2H)\text{-}CH_2\text{-}CO_2H$

Oxalic acid, MW = 90
$HO_2C\text{—}CO_2H$

Parts 4 -5: EW from Experiment Data

- Experimentally determine the equivalent weight of a carboxylic acid by titration

- EW = Mass (g) of acid providing 1 mol H^+ or neutralizing 1 mol OH^-.

$$EW = \frac{\text{mass acid (g)}}{\text{moles of } OH^- \text{ neutralized}}$$

Part 4: Equivalent Weight Practice

Mass of acid = _____; mol of OH^- neutralized = _____

EW of Oxalic Acid (Part 4)

Q. 34.90 mL of 0.10 M NaOH neutralizes 0.22 grams of acid. What is the equivalent weight of the acid?

Answer.
0.22 g acid neutralized 3.49 mmol of NaOH.
The mass of acid needed to neutralize 1 mol = ?

63.04 g/mol = EW

Sample = oxalic acid dihydrate,
$HOOCCOOH \cdot 2H_2O$

(MW = 126.07; EW = 63.04g/mol)

Equivalent Weight Errors

1. Acid mass is incorrect
2. Sample is not all transferred to titration flask
3. Buret tip is not filled with titrant
4. Buret volume readings are incorrect
5. Titration flask and contents not mixed properly
6. Incorrect indicator used to monitor titration
7. Recorded volume of delivered base is incorrect

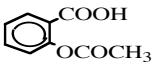
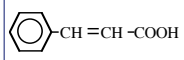
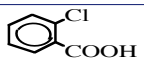
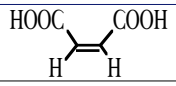
$$EW = \frac{\text{mass acid (g)}}{\text{moles of } OH^- \text{ neutralized}}$$

Q. Error 2 will result in an EW that is greater than true. Why?

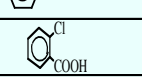
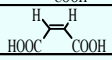
Part 5. Identification of an Unknown Acid

- Identify a carboxylic acid from melting point and equivalent weight titration data

- Determine the approximate volume of NaOH needed to neutralize a mass of unknown acid BEFORE conducting a quantitative determination of the equivalent weight by titration
- Practice melting point and equivalent weight skills with known compounds BEFORE testing the unknown
- Determine the approximate melting point range (e.g., 110 -130ºC) BEFORE quantitatively determining the actual melting point range

See Table, p.118 Name	Formula	MW	EW	MP
2-hydroxybenzoic acid acetate		180	180	135
trans-cinnamic acid		148	148	135-136
2-chlorobenzoic acid		157	157	140
cis-butenedioic (maleic) acid		116	58	139-140

Q. You titrate 0.175 g of an acid. 30.00 mL of 0.10 M NaOH neutralizes the sample. Identify the acid from the list below.

Name	Formula	MW	MP
2-hydroxybenzoic acid acetate		180	135
trans-cinnamic acid		148	135-136
2-chlorobenzoic acid		157	140
cis-butenedioic (maleic) acid		116	139-140

Equivalent weight determination.

1) Determine mol of NaOH the acid has neutralized.

Fact: The acid mass neutralized 30.00 mL of 0.10 M NaOH

$$\text{mol } OH^- = V(L) \times M \text{ NaOH}$$

$$= 0.0300\text{L} \times \frac{0.10 \text{ mol}}{1\text{L}}$$

$$= 3.0 \times 10^{-3} \text{ mol}$$

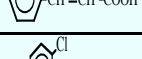
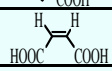
Equivalent Weight determination.

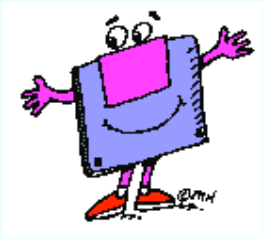
2) Determine the mass of acid that would neutralize one mol of hydroxide ions.

$$\text{Known: } \frac{0.175 \text{ g}}{\text{X g acid}} = \frac{0.0030 \text{ mol } OH^-}{1 \text{ mol } OH^-}$$

X = 58 g

Q. What is the identity of the acid if EW = 58?

Name	Formula	MW	MP
2-hydroxybenzoic acid acetate		180	135
trans-cinnamic acid		148	135-136
2-chlorobenzoic acid		157	140
cis-butenedioic (maleic) acid √		116	139-140



Questions?

Contact nkerner@umich.edu