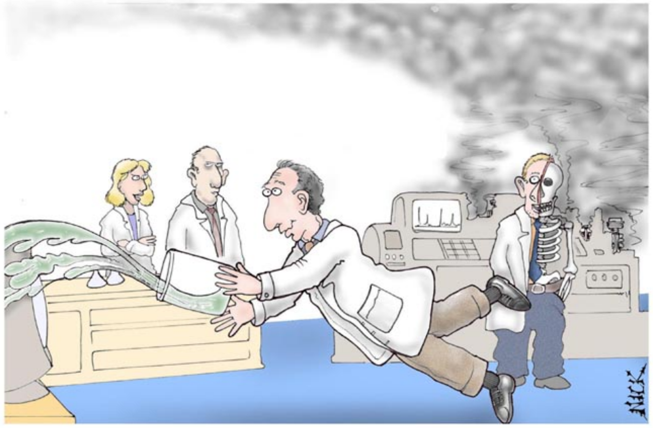
Chemistry BC2001x
Lab Week 7: Acid-base Titration



When Chemists take acid trips.

ACID-BASE titrations

$H^+(aq)$ and $NO_3^-(aq)$ $KOH(s)$

Solutions: concentrations

various units: all are **RATIOS**

weight % Q		100 x (g Q / total g)
mole fraction X_Q		moles Q / total moles
molality m		moles Q / kg solvent
molarity M	[Q] =	moles Q / L solution
	=	mmol Q / mL solution
normality N		equivalents Q / L solution

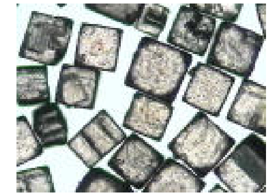
Concentrations of homogeneous solutions

- Like temperature, density, and pressure, concentration is an intensive property:
  - does not depend on how much solution you have
  - is the same whether you take a drop of solution or a the whole bottle
- Mass, volume, and moles are extensive:
  - they scale with the system
  - If you take a larger sample, they are all larger.
- Concentrations are ratios of extensive properties

Concentrations of homogeneous solutions

- To calculate the concentration of a solution, you must work with some amount.
- The choice is often arbitrary: ALWAYS SPECIFY YOUR CHOICE … that way you won't lose track later.
  - "Consider 100 g of solution..."
  - "Consider 1 L of solution…"
- A judicious choice often makes solving the problem much easier
- Today we will review this with four problems. (This material was in problem set 5)

Concentration problems Example 1



The solubility of ordinary salt in water at 25°C is 36.5 g NaCl per 100 mL solution.
What is the molarity of a saturated NaCl solution?

Formula weight NaCl: 58.44277 g/mole

Consider 100 mL of a saturated solution

it contains 36.5 g NaCl

(36.5 g NaCl)/(58.4427 g/mole) = 0.62454 moles

in how many Liters? 100 mL = 0.100 L

Concentration problems
Example 1, page 2

Molarity = (moles solute)/(L solution)
= (0.62454 moles NaCl)/(0.100 L)

[NaCl] = 6.25 M

Could also work with millimoles and milliliters:
1000 mmoles = 1 mole, 1000 mL = 1 L, so

Molarity = (mmoles solute)/(mL solution)

0.62454 moles NaCl in 0.100 L
= 624.54 mmoles in 100 mL

Molarity = 625 mmoles /100 mL = 6.25 M

Concentration problems
Example 2

Give detailed instructions for preparing 500.0 mL of 0.100 M $KMnO_4$ (potassium permanganate) solution, a deep purple solution used in redox chemistry.

formula weight of $KMnO_4$ = 158.034

Here the amount IS specified: 500 mL

How many mmoles of $KMnO_4$ do we want?

(molarity)(mL) = mmoles

(0.100 M)(500 mL) = 50.0 mmoles $KMnO_4$

example 2: continued
making 500.0 mL of 0.100 M $KMnO_4$

formula weight of $KMnO_4$ is 158.034 g/mole
50.0 mmoles $KMnO_4$ (or 0.0500 moles)
How to measure?
It is a solid salt, so we can weigh it.
(formula weight) = grams/moles
so grams = (formula weight) x (moles)
OR mg = (formula weight) x (mmoles)
mg $KMnO_4$ = (158.034 mg/mmol) (50 mmol)
= 7901.697 mg $KMnO_4$
or 7.901697 g $KMnO_4$

example 2 (continued)
preparing 500.0 mL of 0.100 M $KMnO_4$

7.901697 g $KMnO_4$
How precisely do we need to weigh this?
IMPORTANT PRACTICAL QUESTION:
It is a lot more time-consuming to measure exactly 7.9017 g than 7.90 g.
USE SIGNIFICANT FIGURES TO DECIDE!
Specified molarity is 0.100,
so 7.90 g is sufficiently precise
(weight of ~7.88 g to ~7.92 g is still ok)
so weigh 7.90 g solid $KMnO_4$

example 2: final slide The Instructions for
preparing 500.0 mL of 0.100 M $KMnO_4$

1) Weigh 7.90 grams $KMnO_4$(s)
2) Transfer this quantitatively into a 500 mL volumetric flask (quantitative transfer = use funnel, rinse the weighing bottle several times with water, pouring the rinses through the funnel)
3) Fill flask about 2/3 with distilled water; mix thoroughly
4) Fill exactly to the mark; mix again.

Concentration problems: Example 3

Give detailed instructions for preparing 250.0 mL of 2.00 M HCl.
We need (250 mL)(2.00 M)
= 500 mmoles HCl
Can we weigh this? NO!
HCl does not come as a pure solid.
HCl(g) is difficult to work with.
Chemical supply companies sell concentrated aqueous HCl (as well as other concentrated acids and bases.)
Concentrated HCl is often 12.0 M
We must dilute this concentrated reagent.

example 3 (page 2)
prepare 250 mL 2.00M HCl from 12.0 M HCl

We need 500 mmoles (0.0500 moles) HCl:

how much 12.0 M solution do we use?

molarity = (mmoles) / (mL)

→ mL = (mmoles) / (molarity)

(500 mmoles) / (12.0 M) = 41.67 mL

Shortcut (for dilution problems):

The number of moles taken from the concentrated solution is the same as the moles in the final dilute solution, so $M_1V_1 = M_2V_2$

$V_2 = V_1(M_1/M_2)$ = (250 mL)(2.00/12.0) = 41.67 mL

(dilution by factor of 6).

example 3 (page 3):
prepare 250 mL 2.00M HCl from 12.0 M HCl

1) Measure 41.67 mL of 12.0 M HCl.
   How? Use a buret.
   41.7 ± 0.1 mL is close enough.
2) Transfer quantitatively to a 250 mL volumetric flask.
3) Fill about 2/3 with distilled water, Mix thoroughly
4) Fill exactly to the mark, and mix again.

Concentration problems: Example 4

How could you determine the molarity of NH_3 in a bottle of household ammonia (NH_3 dissolved in water)?

NH_3 is a base. The moles present in a sample can be determined by acid-base titration:

Measure a volume of the ammonia.

Titrate with standardized acid solution (e.g. HCl) until the solution becomes acidic (equivalence point is reached). Repeat.

example 4 (continued)
Molarity of household ammonia

Titration reaction:

$$NH_3(aq) + H^+(aq) \rightarrow NH_4^+(aq)$$

or $NH_3(aq) + H_3O^+(aq) \rightarrow NH_4^+(aq) + H_2O(l)$

Cl^- is not written in the net ionic equation

Since HCl is a strong acid, Cl^- is a spectator.

Start with a precise volume of ammonia solution.

How? Use a volumetric pipet.

Stoichiometry of titration reaction is 1:1

at equivalence point moles acid = moles base

(moles acid added) = (moles base initially)

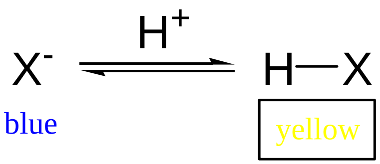
example 4 (page 3): Molarity of household ammonia

How do we find the equivalence point?

Use an indicator: added substance that changes color when solution changes from basic to acidic.

This happens within a drop.

Stop when the color changes: the endpoint.

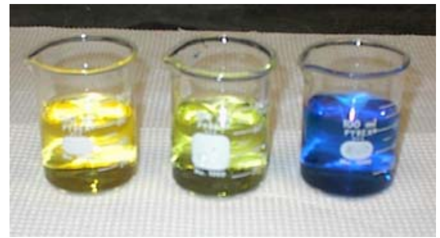


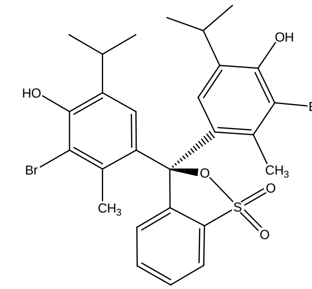
Example of an Indicator (used in lecture)

bromothymol blue

yellow in acid

blue in base





example 4 (continued): Molarity of household ammonia

50.0 mL of household ammonia solution is titrated with 0.100 M HCl.

The endpoint is reached at 42.13 mL.

What is the molarity of this ammonia?

At equivalence,

(42.13 mL)(0.100 M) = 4.213 mmoles acid added

moles acid added = moles base initially, so

4.213 mmoles base was in the original 50.0 mL

$[NH_3]$ = (4.213 mmole)/(50.0 mL) = 0.0843 M

Molarity of household ammonia some procedural questions...

Can you add water during the titration?

- Yes, this will not change the moles present

Some ammonia solution is put into a beaker from which the sample is taken by pipet. Can there be water in that beaker?

- NO! This would change the molarity of the solution you will take into the pipet.

What do you do if you have no dry beakers?

- Ask your lab instructor for advice..