More Stoichiometric Calculations
(involving titration references)

Example #1 (multiple choice type question)

25.0mL of LiOH (aq) was titrated to its endpoint with HBr (aq) . The buret recorded a volume of 20.4 mL. If the concentration of the base was 0.50M, calculate the concentration of the acid.

LiOH (aq) + HBr (aq) → LiBr (aq) + HOH (l)
sample titrant
25.0mL 20.4 mL
0.50 M

$n_a = n_b$ (1:1 mole ratio)
$C_a v_a = C_b v_b$
$C_a = \underline{C_b v_b}$

$v_a = \underline{(0.50M)(25.0mL)}$
20.4 mL
$C_a = 0.61$ mol/L

Example #2 (another m.c)
You titrated 50.0mL of HCl (aq) with 0.44M KOH (aq). The initial buret reading was 0.23 mL and the final buret reading was 32.11 mL. Calculate the unknown concentration
HCl (aq) + KOH (aq) → KCl (aq) + HOH (l)
sample titrant
50.0mL 0.44 M
31.88 mL*

*Final reading - initial reading = total volume of KOH used.
32.11 mL - 0.23 mL = 31.88 mL

$n_a = n_b$ So $C_a v_a = C_b v_b$
$C_a = \underline{C_b v_b}$
v_a

$= \underline{(0.44\ M)\ (\ 31.88\ mL)}$
50.0 mL

$= 0.28$ M

Example #3
Calculate the molar concentration of acid given the following information:

Titration of 50.0mL samples of 0.10M NaOH with HCl

Trial	1	2	3	4
final buret reading	34.28	35.61	34.93	35.32
initial buret reading	0.26	1.35	0.85	1.22

First check to see how much titrant was added .

Trial #1 34.02
#2 34.26*
#3 34.08
#4 34.10

* You can throw this one out and average the other three because this value does not fit.

Average volume added 34.07 mL

Write and balance the equation:

$NaOH\ (aq) + HCl\ (aq) \rightarrow HOH\ (l) + NaCl\ (aq)$

Sample	Titrant
(Known)	(Unknown)
50.0mL	34.07mL

$n_a = n_b$ (1:1 mole ratio)

$C_a v_a = C_b v_b$

$C_a = \frac{C_b v_b}{v_a}$

$C_a = \frac{0.10\ M \times 50.0mL}{34.07\ mL}$

$= 0.15\ M$

Example #4
A solution of boric acid was titrated to the second endpoint with 0.15 M NaOH (aq). An average of 26.7 mL of the base was required to react with 30.0 mL samples of the acid. Calculate the concentration of the acid.

Write and balance equation:
H_3BO_3 (aq) + 3NaOH (aq) → Na_3BO_3 (aq) + 3HOH (l)
BUT - this is only to the second endpoint, that is, only 2 H will react not all three, so the mole ratio of boric acid to sodium hydroxide is only 1:2 not 1:3!

C_a = ? C_b = 0.15 M
v_a = 30.0 mL v_b = 26.7 mL

$$C_a = \frac{C_b v_b}{v_a} = \frac{0.15\ M \times 26.7\ mL}{30.0\ mL} = 0.134\ M$$

Multiply by mole ratio:
0.134 M x ½ = 0.067 M

Calculations Involving Excess and Limiting Reagents

More often than not, there will be a calculation of an acid-base reaction involving limiting and excess reagents. When they ask for the pH of a final mixture, it is determined by the reagent in excess.

You may be asked for the pH, pOH, hydronium ion concentration, or hydroxide ion concentration, in a strong acid/ strong base mixture given an excess of one reagent, with a mole ratio of 1:1, even in multiple choice!

Example #1 26.7mL of 0.57 M NaOH(aq) was mixed with 45.8 mL of 0.41 M HCl (aq). Calculate the pH of the final mixture.

NaOH (aq) + HCl (aq) → NaCl (aq) + HOH (l)
26.7mL 45.8mL
0.57 M 0.41 M

Find the number of moles of each, since it's a 1:1 ratio, the greater number of moles in excess.

n of NaOH = Cv
= 0.57 M x 26.7 mL
= 0.57 M x 0.0267 L
= 1.52×10^{-2} mol

n of HCl = Cv
= 0.41M x 0.0458L
= 1.88×10^{-2} mol

HCl (aq) is in excess and NaOH is the limiting reagent!

Since they react in a 1:1 ratio, we can subtract to find out how many moles are left over.

$\mathbf{n_{leftover} = n_{initial} - (n_{limiting} \times wanted/given)}$
$= 1.88 \times 10^{-2}$ mol - 1.52×10^{-2} mol
$= 3.6 \times 10^{-3}$ mol

To find pH we need the concentration of hydronium ions, which will be the same as the concentration of HCl (aq) (1: 1 ratio)

$$[HCl]_{leftover} = \frac{n_{leftover}}{v\ (total)}$$

$$= \frac{3.6 \times 10^{3}\ mol}{(26.7 + 45.8)mL}$$

$$= \frac{3.6 \times 10^{-3}\ mol}{72.5\ mL}$$

$= 0.0497$ mol/L $= [H_3O^+]$

pH $= -\log [H_3O^+]$
$= -\log (0.0497)$
$= 1.30$

Example #2 (Multiple Choice type)
75.0mL of aqueous 0.100 M sodium hydroxide was mixed with 50.0 mL of 0.100 M HCl (aq), what is the resulting pH?

$$NaOH\ (aq) + HCl\ (aq) \rightarrow NaCl\ (aq) + HOH\ (aq)$$

v= 75.0mL 50.0mL
C=0.100M 0.100 M

Since it's a 1:1 , and the concentrations are equal , we can identify the NaOH as the excess species

The number of moles leftover (n) = Cv
= 0.100 M x 25.0 mL
= 0.100 mol/L x 0.0250 L
= 0.00250 mol

Concentration of this excess C = n/v
= 0.00250 mol / 125 mL
= 0.00250 mol / 0.125 L
= 0.0200 M

pH = 14 - pOH
= 14 - (-log [0.0200])
= 14 - (-log 0.00200)
= 14 - 1.70
= 12.30

Please note:

- Sometimes the terminology will refer to the endpoint of a titration. If the endpoint is missed, the titrant is the excess reagent. A simple calculation should give you the moles of the excess reagent.

- If the mole ration is not 1:1, which is highly unlikely, the ratio might be used in two places - both for moles of the excess reagent left over, and the determination of excess/limiting reagent

- BE CAREFUL if your acid and base are not mono- use an internal mole ratio to determine the concentration of H^+ or OH^- before you find pH or pOH

Try this one:
What is the pH of a solution created by mixing 15.0mL of 0.50 M HCl (aq) with 35.0mL of 1.0 M NaOH (aq) ?