CHEMISTRY: ACID -BASE CALCULATIONS

Questions to ask yourself? (particularly if it looks like a more complex problem)

1. Is there a chemical reaction happening? If yes then you may need to think about a mole to mole ratio or even which is the limiting reagent in some cases.
2. Is it just a dilution? If all you are doing is adding water then maybe you can use the formula $c_1v_1 = c_2v_2$
3. Are you adding two different samples of the same chemical to each other? In this case you are likely to have to work out the total number of moles

Let's try some problems.

1. If 100 mL of water is added to 100 mL of 2M HCl then what will be the pH of the resulting solution?
2. If 100 mL of 2M HCl is added to 200mL of 1M HCl then what will be the pH of the new solution?
3. What is the pH of a 100 mL sample of 2M NaOH?
4. If 50 mL of 2M H_2SO_4 is added to 50mL of 2M NaOH then what will be the pH of the final solution?
5. What will be the pH of a 0.05M solution of $Ba(OH)_2$?

Question 39 2011 WACE examination

A student was given three bottles, A, B and C. Each bottle was labelled with its contents as shown in the table below.

bottle	contents
A	46.5 mL of 0.010 mol L^{-1} HCl
B	65.7 mL of 0.0555 molL^{-1} HNO_3
C	20.9 mL of 0.4161 mol L^{-1} NaOH

a) Calculate the pH of the NaOH solution (2 marks)

b) The contents of all three bottles are placed in one beaker and mixed thoroughly. Calculate the pH of the final mixture. (10 marks)

Acid- Base Calculations - pH

1 HCl $V = 100mL$, $c = 2M$

100mL of water is added
this is a dilution so $c_1V_1 = c_2V_2$
can be used to find new $[H^+]$

$C_1V_1 = C_2V_2$
$(2)(0.1) = C_2(0.2)$
$\Rightarrow C_2 = 1M$

$HCl \rightarrow H^+ + Cl^-$
$1M \quad\quad 1M$

$pH = -\log[H^+] = -\log 1 = 0$

2 HCl $V = 100mL$, $c = 2M$

$n = cV$
$= (2)(0.1)$
$= 0.2 mol$

added to HCl $V = 200mL$, $c = 1M$

$n = cV$
$= (1)(0.2)$
$= 0.2 mol$

$n_{total\ HCl} = 0.2 + 0.2 = 0.4 mol$

$C_{HCl\ in\ mixture} = \frac{n}{V} = \frac{0.4}{0.3} = 1.33M$

$HCl \rightarrow H^+ + Cl^-$
$1.33M \quad\quad 1.33M$

$pH = -\log 1.33 = -0.124$

3

$$NaOH \rightarrow Na^+ + OH^-$$
2M   2M

$$K_w = 1\times10^{-14} = [H^+][OH^-]$$

$$\frac{1\times10^{-14}}{2} = [H^+]$$

$$[H^+] = 5\times10^{-15}$$

$$pH = -\log 5\times10^{-15} = 14.3$$

4 this question involves chemical reaction, I will need to find limiting reagent.

$$H_2SO_4 + 2NaOH \rightarrow H_2O + Na_2SO_4$$

H_2SO_4: $V = 50\,mL$, $c = 2M$, $n = cV = (2)(0.05) = 0.1\,mol$

$NaOH$: $V = 50\,mL$, $c = 2M$, $n = cV = (2)(0.05) = 0.1\,mol$

need $\frac{H_2SO_4}{NaOH} = \frac{1}{2} = \frac{0.5}{1}$ given $\frac{H_2SO_4}{NaOH} = \frac{0.1}{0.1} = \frac{1}{1}$

$\therefore$ NaOH is L.R.

Now need to find moles of excess reagent leftover.

$n_{H_2SO_4}$ that does react $= \frac{1}{2}\times n_{NaOH} = \frac{1}{2}\times 0.1 = 0.05\,mol$

$n_{H_2SO_4}$ leftover $= 0.1 - 0.05 = 0.05\,mol$

$c_{H_2SO_4}$ in final mixture $= \frac{n}{V} = \frac{0.05}{0.1} = 0.5\,M$

$$H_2SO_4 \rightarrow 2H^+ + SO_4^{2-}$$
0.5M   1M

$$pH = -\log 1 = 0$$

5. $Ba(OH)_2 \rightarrow Ba^{2+} + 2OH^-$

$0.05M$ $\quad$ $0.1M$

$1\times10^{-14} = [H^+][OH^-]$

$1\times10^{-14} = [H^+](0.1)$

$\Rightarrow [H^+] = \frac{1\times10^{-14}}{0.1} = 1\times10^{-13}$

$pH = -\log 1\times10^{-13} = 13$

Question 39 2011 WACE EXAM.

a) $NaOH \rightarrow Na^+ + OH^-$

0.4161 $\quad$ 0.4161

$[H^+] = \frac{1\times10^{-14}}{0.4161} = 2.4\times10^{-14}$

$pH = -\log 2.4\times10^{-14} = 13.6$

b) when I mix all three bottles I will get a reaction between H^+ and OH^- the first thing I have to do is figure out total moles of H^+ and total moles of OH^- and then decide what the limiting reagent is.

$n_{NaOH} = cV = (0.4161)(0.0209) = 0.00870$ mol

$n_{OH^-} = n_{NaOH} = \underline{0.00870 \text{ mol}}$

$n_{HCl} = cV = (0.010)(0.0465) = 0.000465$ mol

$n_{H^+} = n_{HCl} = 0.000465$ mol

$n_{HNO_3} = cV = (0.0555)(0.0657) = 0.00365$ mol

$n_{H^+} = n_{HNO_3} = 0.00365$ mol

$n_{H^+} \text{ total} = 0.000465 + 0.00365 = \underline{0.00411}$ mol

$$H^+ + OH^- \rightarrow H_2O$$

need $\frac{H^+}{OH^-} = \frac{1}{1}$ given $\frac{H^+}{OH^-} = \frac{0.00411}{0.00870} = \frac{0.47}{1}$

$\therefore$ H^+ is limiting reagent

Now need to find moles of excess reagent remaining.

$$n_{OH^- \text{ reacting}} = \frac{1}{1} \times n_{H^+} = 0.00411$$

$$n_{OH^- \text{ leftover}} = 0.00870 - 0.00411 = 0.00459 \text{ mol}$$

$$C_{OH^-} \text{ in final mixture} = \frac{n}{V} = \frac{0.00459}{0.0465 + 0.0657 + 0.0209}$$

$$= \frac{0.00459}{0.1331}$$

$$= 0.0345M$$

$$[H^+] = \frac{1 \times 10^{-14}}{0.0345} = 2.90 \times 10^{-13}$$

$$pH = -\log 2.9 \times 10^{-13}$$

$$= 12.5$$