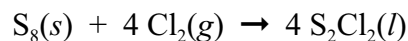


## Detailed Solutions to Limiting Reagent Problems

1. Disulfur dichloride is prepared by direct reaction of the elements:



What is the maximum amount of  $\text{S}_2\text{Cl}_2$  that could be made by the reaction of 64.0 g of sulfur with 142 g of chlorine? What quantity of which reagent would remain unreacted?

we have  $64.0 / 256.5 = 0.249$  mol  $\text{S}_8$

and  $142 / 71.0 = 2.00$  mol  $\text{Cl}_2$ ; the ratio  $\text{Cl}_2 / \text{S}_8$  is  $2.00 / 0.249 = 8.0$

but the reaction only requires 4 mol of  $\text{Cl}_2$  per mol of  $\text{S}_8$

so  $\text{Cl}_2$  is in excess and  $\text{S}_8$  is limiting

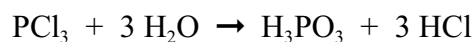
0.249 mol  $\text{S}_8$  give  $0.249 \times 4 = 0.998$  mol  $\text{S}_2\text{Cl}_2$

mass  $0.998 \times 135.1 = 135$  g  $\text{S}_2\text{Cl}_2$

this needs  $0.249 \times 4 = 0.998$  mol  $\text{Cl}_2$

remaining  $\text{Cl}_2$   $2.00 - 0.998 = 1.00$  mol, mass 71.0 g

2. Phosphorus trichloride reacts with water according to the stoichiometry:



A 200 g sample of  $\text{PCl}_3$  was reacted with excess water and 120 g of  $\text{HCl}$  was isolated.

What was the percent yield of  $\text{HCl}$  in this experiment?

*Either masses or moles may be compared. Here we compare 'moles expected' with 'moles obtained'*

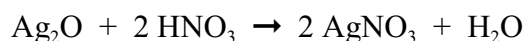
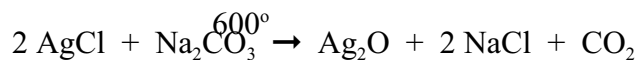
200 g  $\text{PCl}_3$  is  $200 / 137.5 = 1.45$  mol

from equation, expect  $1.45 \times 3 = 4.36$  mol  $\text{HCl}$

actual yield 120 g or  $120 / 36.5 = 3.29$  mol

yield  $100 \times 3.29 / 4.36 = 75.3\%$

3. Silver, an expensive metal, may be recovered from waste  $\text{AgCl}$  by the reactions:



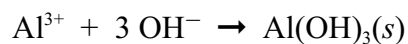
250 g of  $\text{AgCl}$  treated in this way yielded 236 of  $\text{AgNO}_3$ . What was the percent yield?

250 g  $\text{AgCl}$  is  $250 / 143.4 = 1.74$  mol, 1:1 stoich, expect 1.74 mol  $\text{AgNO}_3$

obtained 236 g or  $236 / 169.9 = 1.39$  mol  $\text{AgNO}_3$

yield  $100 \times 1.39 / 1.74 = 79.6\%$

4. Aluminum hydroxide is insoluble in water. Write a balanced equation for the reaction of aqueous  $\text{Al}(\text{NO}_3)_3$  with aqueous  $\text{NaOH}$ . If 75.0 g of hydrated  $\text{Al}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$  is dissolved in water and reacted with 20.5 g of  $\text{NaOH}$ , what mass of  $\text{Al}(\text{OH})_3$  would be formed?



$$\text{Al}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O} \quad 75.0 / 375 = 0.200 \text{ mol}$$

$$\text{NaOH} \quad 20.5 / 40.0 = 0.513 \text{ mol}$$

ratio  $\text{OH}^- / \text{Al} = 2.56$ , less than required 3:1,  $\text{OH}^-$  limiting

$$\text{Al}(\text{OH})_3 \text{ formed } 0.513 / 3 = 0.171 \text{ mol, mass } 0.171 \times 78.0 = 13.3 \text{ g}$$

5. Ethyl cyanide is prepared from ethyl bromide by the reaction:



If 8.53 g of  $\text{NaCN}$  is reacted with 11.0 g of  $\text{C}_2\text{H}_5\text{Br}$ , what mass of  $\text{C}_2\text{H}_5\text{CN}$  will be formed? If the density of  $\text{C}_2\text{H}_5\text{CN}$  is  $0.783 \text{ g mL}^{-1}$ , what volume would this occupy?

$$8.53 \text{ g NaCN is } 8.53 / 49 = 0.174 \text{ mol}$$

$$11.0 \text{ g C}_2\text{H}_5\text{Br is } 11.0 / 108.9 = 0.101 \text{ mol}$$

stoich required is 1:1,  $\text{C}_2\text{H}_5\text{Br}$  is limiting

$$\text{obtain } 0.101 \text{ mol C}_2\text{H}_5\text{CN, mass } 0.101 \times 55.0 = 5.56 \text{ g}$$

$$\text{volume } (5.56 \text{ g}) / (0.783 \text{ g mL}^{-1}) = 7.10 \text{ mL}$$

6. A 12.0 g sample of a mixture containing  $\text{NaNO}_3$  and  $\text{NaCl}$  only is dissolved in water and excess  $\text{AgNO}_3$  solution is added. If 0.120 mol of insoluble  $\text{AgCl}$  precipitates, what is the percent by mass of  $\text{NaCl}$  in the mixture?

1:1 stoich, 0.120 mol of  $\text{NaCl}$  present

$$\text{mass of NaCl} = 0.120 \times 58.5 = 7.02 \text{ g}$$

$$\text{percent NaCl} = 100 \times 7.02 / 12.0 = 58.5\%$$

7. Calcium carbide,  $\text{CaC}_2$ , reacts with water to produce acetylene,  $\text{C}_2\text{H}_2$ , and  $\text{Ca}(\text{OH})_2$ .

(a) Write a balanced equation for this reaction. See answer

(b) What mass of pure  $\text{CaC}_2$  must be added to excess water to produce 41.6 g  $\text{C}_2\text{H}_2$ ?

$$41.6 \text{ g C}_2\text{H}_2 \text{ is } 41.6 / 26.0 = 1.60 \text{ mol}$$

1:1 stoich, comes from 1.60 mol  $\text{CaC}_2$

$$\text{mass of CaC}_2 \quad 1.60 \times 64.0 = 102 \text{ g pure CaC}_2$$

(c) Calcium carbide is commonly less than 100% pure. If the sample used in (b) above had a purity of 90% by mass, the remainder being unreactive  $\text{CaCO}_3$ , what mass would be required?

$$102 \times 100 / 90 = 114 \text{ g impure CaC}_2$$

8. Dinitrogen pentoxide is made by the reaction:



15.1 g of  $\text{P}_4\text{O}_{10}$  is heated with 10.7 g of  $\text{HNO}_3$ . Calculate:

- (a) what is the maximum amount of  $\text{N}_2\text{O}_5$  that could be formed?

$$15.1 \text{ g } \text{P}_4\text{O}_{10} \text{ is } 15.1 / 284 = 0.0532 \text{ mol}$$

$$10.7 \text{ g } \text{HNO}_3 \text{ is } 10.7 / 63.0 = 0.170 \text{ mol}$$

ratio  $\text{HNO}_3 / \text{P}_4\text{O}_{10} = 3.2$ , less than required 4:1,  $\text{HNO}_3$  limiting

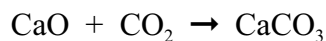
$$\text{N}_2\text{O}_5 \text{ produced } 0.170 / 2 = 0.085 \text{ mol}$$

$$\text{mass } 0.085 \times 108 = 9.17 \text{ g}$$

- (b) if only 1.96 g of  $\text{N}_2\text{O}_5$  is obtained, what is the percent yield in the reaction?

$$100 \times 1.96 / 9.17 = 21.4\% \text{ yield}$$

9. A mixture of  $\text{CaCl}_2$  and  $\text{CaO}$  is known to contain 55% by mass  $\text{CaCl}_2$ . What is the maximum amount of  $\text{CaCO}_3$  that could be produced by the reaction of 100 g of this mixture with 50.0 g of  $\text{CO}_2$ ? The reaction is:



45%  $\text{CaO}$ , so 100 g contains 45 g  $\text{CaO}$

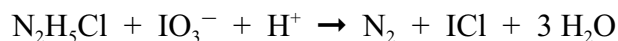
$$\text{this is } 45 / 56 = 0.804 \text{ mol } \text{CaO}$$

$$\text{CO}_2 \text{ present } 50 / 44.0 = 1.14 \text{ mol}$$

1:1 stoich, so  $\text{CaO}$  is limiting

$$\text{obtain } 0.804 \text{ mol } \text{CaCO}_3, \text{ mass } 0.804 \times 100 = 80.4 \text{ g } \text{CaCO}_3$$

10. Hydrazine hydrochloride,  $\text{N}_2\text{H}_5\text{Cl}$ , is oxidized by potassium iodate according to:



When sample of impure  $\text{N}_2\text{H}_5\text{Cl}$ , mass 1.00 g, is oxidized in this way, 224 mL of  $\text{N}_2$  gas are evolved. What is the percent purity of the sample?

(The molar volume of  $\text{N}_2$  is  $22.4 \text{ L mol}^{-1}$ )

$$\text{mol of } \text{N}_2 \text{ evolved } 224 \text{ mL} / 22400 \text{ mL mol}^{-1} = 0.0100 \text{ mol}$$

$$\text{from } 0.0100 \text{ mol } \text{N}_2\text{H}_5\text{Cl}, \text{ mass } 0.0100 \times 68.5 = 0.685 \text{ g pure compound}$$

$$\text{purity } 100 \times 0.685 / 1.00 = 68.5\%$$

11. A sample of a mixture of  $\text{CaCl}_2$  and  $\text{NaCl}$ , total mass 5.34 g, was dissolved in water and excess of sodium oxalate,  $\text{Na}_2\text{C}_2\text{O}_4$ , solution added. If the mass of insoluble calcium oxalate,  $\text{CaC}_2\text{O}_4$ , precipitated was 3.84 g, what was the composition of the mixture?

(a) expressed as percent by mass of  $\text{CaCl}_2$



3.84 g  $\text{CaC}_2\text{O}_4$  is  $3.84 / 128 = 0.0300$  mol

from 0.0300 mol  $\text{CaCl}_2$ , mass  $0.0300 \times 111 = 3.33$  g  $\text{CaCl}_2$

mass composition  $100 \times 3.33 / 5.34 = 62.4\%$   $\text{CaCl}_2$

*Note:* It is not necessary to know the identity of the second component when working out the *mass* composition

(b) expressed as mole percent  $\text{CaCl}_2$

defined as (mol of  $\text{CaCl}_2$ ) / (total mol present)

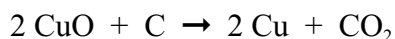
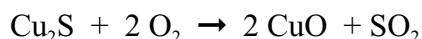
*now we must know the identity and molar mass of the second component*

mass of  $\text{NaCl} = 5.34 - 3.33 = 2.01$  g  $\text{NaCl}$

which is  $2.01 / 58.5 = 0.0344$  mol  $\text{NaCl}$

mol %  $\text{CaCl}_2 = 100 \times 0.0300 / (0.0300 + 0.0344) = 46.6\%$

12. An impure sulfide ore contains 26.0%  $\text{Cu}_2\text{S}$  by mass. It is converted to copper metal by the sequence:



What mass of ore would be needed to produce 1.00 kg of copper metal?

1.00 kg Cu is  $1000 / 63.5 = 15.7$  mol Cu from  $15.7 / 2 = 7.87$  mol  $\text{Cu}_2\text{S}$

mass  $7.87 \times 159.1 = 1253$  g or 1.25 kg  $\text{Cu}_2\text{S}$

contained in  $1.25 \times 100 / 26.0 = 4.82$  kg of ore

13. A deposit of uranium ore contains 0.40% by mass of the oxide  $\text{U}_3\text{O}_8$ .

What mass of this ore would be required to produce 1.0 kg of uranium metal?

see detailed answer, INTRO, p.10

14. Fluoride may be estimated gravimetrically as lead chloride fluoride,  $\text{PbFCl}$ .

A sample of mass 0.800 g of a mixed mineral known to contain  $\text{CaF}_2$  yielded 2.615 g of  $\text{PbFCl}$ . What was the mass percent of  $\text{CaF}_2$  in the mineral?

2.615 g  $\text{PbFCl}$  is  $2.615 / 261.7 = 0.0100$  mol

since  $\text{CaF}_2$  contains *two*  $\text{F}^-$  in the mole, this is from

$0.0100 / 2 = 0.00500$  mol  $\text{CaF}_2$  of mass  $0.00500 \times 78.0 = 0.390$  g

mass %  $\text{CaF}_2 = 100 \times 0.390 / 0.800 = 48.8\%$

## DETAILED ANSWERS to STRONG ACIDS AND BASES

1. (i) (a) monoprotic,  $[\text{H}^+] = 0.025 / 0.400 = 0.0625 \text{ M}$ ,  $\text{pH} = 1.20$   
(b) diprotic,  $[\text{H}^+] = 2 \times 0.600 / 1.50 = 0.800 \text{ M}$ ,  $\text{pH} = 0.10$   
(ii) (a) monoprotic,  $[\text{OH}^-] = 0.350 / 0.600 = 0.583 \text{ M}$ ,  $\text{pOH} = 0.23$ ,  $\text{pH} = 13.77$   
(b) diprotic,  $[\text{OH}^-] = 2 \times 0.450 / 2.50 = 0.360 \text{ M}$ ,  $\text{pOH} = 0.44$ ,  $\text{pH} = 13.56$   
(iii) (a)  $[\text{H}^+] = [\text{HCl}] = 3.16 \times 10^{-3} \text{ M}$   
(b)  $3.16 \times 10^{-3} \times 36.5 = 0.115 \text{ g L}^{-1}$   
(iv) (a) diprotic,  $[\text{H}^+] = 0.126 \text{ M}$ ,  $[\text{H}_2\text{SO}_4] = 0.126 / 2 = 0.063 \text{ M}$   
(b)  $0.063 \times 98 = 6.2 \text{ g L}^{-1}$   
(v) (a) monoprotic,  $\text{pOH} = 14 - 12.50 = 1.50$ ,  $[\text{KOH}] = 0.0316 \text{ M}$   
(b)  $0.0316 \times 56.0 = 1.77 \text{ g L}^{-1}$   
(vi) diprotic,  $\text{pOH} = 3.50$ ,  $[\text{OH}^-] = 3.2 \times 10^{-4} \text{ M}$   
 $[\text{Ca}(\text{OH})_2] = 3.2 \times 10^{-4} / 2 = 1.6 \times 10^{-4} \text{ M}$   
(b)  $1.6 \times 10^{-4} \times 74.0 = 0.0117 \text{ g L}^{-1}$
2. (i)  $[\text{H}^+] = 0.200 \times 25.0 / 350 = 0.0143 \text{ M}$ ,  $\text{pH} = 1.85$   
(ii)  $[\text{OH}^-] = 0.240 \times 0.125 / 1.00 = 0.0300 \text{ M}$ ,  $\text{pOH} = 1.52$ ,  $\text{pH} = 12.48$
3. take 1 L of HCl, mol of HCl = mol of NaCl = 0.150  
vol NaOH required  $0.150 / 0.100 = 1.5 \text{ L}$ , total volume 2.5 L  
 $[\text{NaCl}] = 0.150 / 2.5 = 0.0600 \text{ M}$
4. need  $0.250 \times 0.200 = 0.0500 \text{ mol HCl}$   
contained in  $0.0500 / 12.0 = 0.00417 \text{ L} = 4.17 \text{ mL conc HCl}$
5. diprotic. need  $[\text{H}^+] = 0.316 \text{ M}$  or  $[\text{H}_2\text{SO}_4] = 0.158 \text{ M}$   
in 0.500 L, 0.0791 mol,  $0.0791 \times 98.0 = 7.76 \text{ g pure H}_2\text{SO}_4$   
or  $7.76 / 0.96 = 8.08 \text{ g impure acid}$ , volume  $8.08 / 1.83 = 4.41 \text{ mL}$
6. diprotic,  $[\text{Ca}(\text{OH})_2] = 1.7 / 74.0 = 0.023 \text{ M}$ ,  $[\text{OH}^-] = 0.046 \text{ M}$ ,  $\text{pH} = 12.66$
7. at  $\text{pH} = 12.00$ ,  $[\text{OH}^-] = 1.00 \times 10^{-2} \text{ M}$   
 $100 \text{ NaOH} = 100 / 40.0 = 2.50 \text{ mol}$   
volume  $2.50 / (1.00 \times 10^{-2}) = 250 \text{ L of solution}$

8. (i) (a) monoprotic,  $40.0 \times 0.150 / 0.200 = 30.0$  mL  
 (b) diprotic,  $2 \times 0.100 \times 0.250 / 0.200 = 0.250$  L  
 (ii) (a) monoprotic,  $50.0 \times 0.400 / 0.150 = 133$  mL  
 (b) diprotic,  $2 \times 0.400 \times 0.350 / 0.150 = 1.87$  L
9. (i) monoprotic,  $[\text{HNO}_3] = 15.00 \times 0.125 / 24.85 = 0.0755$  M  
 (ii) diprotic,  $[\text{NaOH}] = 2 \times 35.00 \times 0.480 / 65.00 = 0.517$  M
10. (a) NaOH  $25.0 \times 0.300 = 7.5$  mmol, HBr  $15.0 \times 0.400 = 6.0$  mmol  
 NaOH excess, 1.5 mmol in total volume 40.0 mL,  $[\text{OH}^-] = 0.0375$  M,  $pH = 12.57$   
 (b)  $\text{HNO}_3$   $15.0 \times 0.250 = 3.75$  mmol,  $\text{Ba}(\text{OH})_2$   $10.0 \times 0.300 = 3.00$  mmol or  
 6.00 mmol  $\text{OH}^-$ , an excess. There remains  $6.00 - 3.75 = 2.25$  mmol  $\text{OH}^-$  in  
 a total 25.0 mL,  $[\text{OH}^-] = 0.0900$  M,  $pH = 12.95$
- (c)  $\text{H}_2\text{SO}_4$   $20.0 \times 0.125 = 2.50$  mmol = 5.00 mmol  $\text{H}^+$   
 $\text{CsOH} = 38.0 \times 0.125 = 4.75$  mmol, excess  $\text{H}^+ = 0.25$  mmol  
 total volume 58.0 mL,  $[\text{H}^+] = 0.25 / 58.0 = 4.3 \times 10^{-3}$  M,  $pH = 2.37$
- (d) NaOH  $1.00 / 40.0 = 0.0250$  mol  
 $\text{HCl}$   $0.100 \text{ L} \times 0.245 \text{ M} = 0.0245$  mol, excess 0.0005 mol  $\text{OH}^-$   
 $[\text{OH}^-] = 0.0005 / 0.100 = 0.005$  M,  $pOH = 11.70$
11. (a) at  $pH$  1.94,  $[\text{H}^+] = 0.0115$  M, monoprotic, so 1.00 mL contained 0.0115 mol  
 which is  $0.0115 \times 100.5 = 1.15$  g  $\text{HClO}_4$ , purity  $100 \times 1.15 / 1.66 = 69.5\%$   
 (b) 0.0115 mol in 1.00 mL is  $0.0115 / 0.00100 = 11.5$  M,  $pH = -1.06$   
 yes, a negative  $pH$  is possible in the rare case of  $[\text{H}^+] > 1$  M
12.  $\text{K}_2\text{O}(s) + \text{H}_2\text{O} \rightarrow 2 \text{K}^+ + 2 \text{OH}^-$   
 1.0 g  $\text{K}_2\text{O}$  is  $1.0 / 94.0 = 0.0106$  mol, gives 0.02123 mol  $\text{OH}^-$   
 $[\text{OH}^-] = 0.02123 / 0.500 = 0.04246$  M,  $pOH = 1.37$ ,  $pH = 12.63$
13. initially  $[\text{H}^+] = 0.398$ , after dilution  $0.398 \times 25.0 / 400 = 0.0249$  M,  $pH = 1.60$
14. initially  $[\text{OH}^-] = 3.16 \times 10^{-2}$ , require  $[\text{OH}^-] = 1.00 \times 10^{-3}$   
 dilute by factor  $(3.16 \times 10^{-2}) / (1.00 \times 10^{-3}) = 31.6$   
 shortcut: difference in  $pH$  is 1.5, dilute by  $10^{1.5} = 31.6$

15.  $\text{KHPH } 1.472 / 204.2 = 7.209 \times 10^{-3} \text{ mol, monoprotic}$   
 $[\text{NaOH}] = (7.209 \times 10^{-3}) / 0.03992 = 0.1806 \text{ M}$
16. mol of base  $0.02350 \times 0.549 = 0.01290 \text{ mol}$   
mass  $0.01290 \times 91.0 = 1.17 \text{ g, conc } 100 \times 1.17 / 5.00 = 23.5\% \text{ by mass}$
17.  $0.0500 \text{ g CaCO}_3 \text{ is } 0.0500 / 100 = 5.00 \times 10^{-4} \text{ mol, diprotic}$   
reacts  $1.00 \times 10^{-3} \text{ mol H}^+$ ,  
 $[\text{H}^+] = 1.00 \times 10^{-3} / 0.0400 = 0.0250 \text{ M}$
18.  $\text{pH } 0.90, [\text{H}^+] = 0.126, \text{ in } 1.50 \text{ L there are } 0.126 \times 1.50 = 0.189 \text{ mol H}^+$   
 $\text{pH } 1.50, [\text{H}^+] = 0.0316, \text{ in } 1.50 \text{ L there are } 0.316 \times 1.50 = 0.0474 \text{ mol H}^+$   
difference  $0.189 - 0.0474 = 0.141 \text{ mol}$   
need  $0.141 / 2 = 0.071 \text{ mol of diprotic Mg(OH)}_2$   
mass  $0.071 \times 58.3 = 4.12 \text{ g}$
19.  $4.00 \text{ g Al is } 4.00 / 27.0 = 0.148 \text{ mol, reacts } 0.148 \times 3 = 0.444 \text{ mol H}^+$   
originally  $0.500 \text{ mol H}^+$ , remaining  $0.0555 \text{ mol in } 0.500 \text{ L,}$   
 $[\text{H}^+] = 0.111 \text{ M, pH} = 0.95, \text{ up from original } \text{pH} = 0.00$
20.  $9.78 \text{ g of KOH is } 9.78 / 56.1 = 0.174 \text{ mol, monoprotic}$   
 $\text{HBr } 0.175 \text{ mol in } 0.0100 \text{ L, conc } 17.4 \text{ M}$   
(solution density is not needed!)
21. take 1 L of each in each case:  
(a)  $\text{H}_2\text{SO}_4 \text{ diprotic, } 0.0400 \text{ mol H}^+$   
 $\text{NaOH } 0.0300 \text{ mol, excess } 0.0100 \text{ mol H}^+ \text{ in } 2 \text{ L}$   
 $[\text{H}^+] = 0.00500, \text{ pH} = 2.30$   
(b)  $0.0180 \text{ mol H}^+ \text{ from HCl}$   
 $\text{Sr(OH)}_2 \text{ diprotic, } 2 \times 0.0120 = 0.0240 \text{ mol OH}^-$   
excess  $0.0060 \text{ mol } [\text{OH}^-] \text{ in } 2 \text{ L, } [\text{OH}^-] = 0.0030 \text{ M, pH} = 11.48$
22.  $[\text{OH}^-] = 3.16 \times 10^{-3} \text{ M, } 0.0158 \text{ mol in } 5.00 \text{ L}$   
required  $3.16 \times 10^{-4} \text{ M, } 0.00158 \text{ mol in } 5.00 \text{ L}$   
difference  $0.0142 \text{ mol, need } 0.0142 \text{ mol of HCl}$   
volume of conc acid  $0.0142 / 12.0 = 0.00119 \text{ L or } 1.19 \text{ mL}$
23. as given answer

24. final solution volume 0.450 L,  $[\text{OH}^-] = 0.0122$ ,  
 $0.0122 \times 0.450 = 0.00505$  mol  $\text{OH}^-$  present  
originally  $0.250 \times 0.300 = 0.0750$  mol  $\text{OH}^-$  present  
mols  $\text{OH}^-$  removed = mol  $\text{HBr} = 0.0750 - 0.00505 = 0.0700$  mol  
 $[\text{HBr}] = 0.0700 / 0.200 = 0.350$  M

25. originally  $4.58 \times 10^{-3} \times 0.650 = 2.98 \times 10^{-3}$  mol  $\text{OH}^-$   
final  $\text{pH} = 10.42$ ,  $[\text{OH}^-] = 2.63 \times 10^{-4}$   
in 650 mL,  $2.63 \times 10^{-4} \times 0.650 = 1.71 \times 10^{-4}$  mol  $\text{OH}^-$   
difference  $2.81 \times 10^{-3}$  mol, need  $1.40 \times 10^{-3}$  mol diprotic  $\text{H}_2\text{SO}_4$

26. Before reaction, 40.0 mL of 0.160 M  $\text{HCl}$  contain  $0.0400 \times 0.160 = 6.4 \times 10^{-3}$  mol  $\text{H}^+$   
After reaction, need 20.0 mL 0.12 M  $\text{NaOH}$ , reacts  $0.0200 \times 0.120 = 2.4 \times 10^{-3}$  mol  $\text{H}^+$   
difference  $4.0 \times 10^{-3}$  mol  $\text{H}^+$  has reacted with  $\text{CaCO}_3$   
reacts 2:1, so reacted with  $2.0 \times 10^{-3}$  mol  $\text{CaCO}_3$ ,  
mass  $2.0 \times 10^{-3} \times 100 = 0.200$  g  $\text{CaCO}_3$   
composition  $100 \times 0.200 / 0.250 = 80\%$   $\text{CaCO}_3$

27. 1:1 reaction, molarity  $112 \times 1.25 / 10.0 = 14.0$  M  
mass of  $\text{NH}_3$  in 1 L,  $14.0 \times 17.0 = 238$  g  
mass of 1 L of solution 880 g, composition  $100 \times 238 / 880 = 27.1\%$   $\text{NH}_3$  by mass