

Stoichiometry Review

1. What is the mass in grams of each of the following?

a. 1.00 mol of Cu $1.00 \text{ mol Cu} \times \frac{64 \text{ g}}{1 \text{ mol}} = 64 \text{ g}$

b. 0.50 mol of S $0.5 \text{ mol S} \times \frac{32 \text{ g}}{1 \text{ mol}} = 16 \text{ g}$

c. 6.02×10^{23} atoms of Ca $6.02 \times 10^{23} \text{ atoms} \times \frac{1 \text{ mol}}{6.02 \times 10^{23} \text{ atoms}} \times \frac{40 \text{ g}}{1 \text{ mol}} = 40 \text{ g}$

2. How many individual atoms are in each of the following?

a. 32.1 mol of sulfur $32.1 \text{ mol S} \times \frac{6.022 \times 10^{23} \text{ atoms}}{1 \text{ mol}} = 1.93 \times 10^{25} \text{ atoms}$

b. 32.1 g of sulfur $32.1 \text{ g} \times \frac{1 \text{ mol}}{32 \text{ g}} \times \frac{6.022 \times 10^{23} \text{ atoms}}{1 \text{ mol}} = 6.04 \times 10^{23} \text{ atoms}$

c. 32.0 g of oxygen $32.0 \text{ g} \times \frac{1 \text{ mol}}{16 \text{ g}} \times \frac{6.022 \times 10^{23}}{1 \text{ mol}} = 1.20 \times 10^{24} \text{ atoms}$

3. A 0.251 g sample of a certain element is the mass of 1.40×10^{21} atoms. What is the element?

$$1.40 \times 10^{21} \text{ atoms} \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ atoms}} = 0.00232 \text{ mol}$$

$$\frac{0.251 \text{ g}}{0.00232 \text{ mol}} = 107.9791 \text{ mol} = \boxed{\text{Ag}}$$

4. What is the mass of 3.00 moles of Na?

$$3 \text{ mol} \times \frac{23 \text{ g}}{1 \text{ mol}} = 69.0 \text{ g}$$

5. How many moles are present in 34.5 g of Na?

$$34.5 \text{ g Na} \times \frac{1 \text{ mol}}{23 \text{ g}} = 1.5 \text{ mol}$$

6. What is the mass of 1.20×10^{24} atoms of Na?

$$1.20 \times 10^{24} \text{ atoms} \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ atoms}} \times \frac{23 \text{ g}}{1 \text{ mol}} = 45.8 \text{ g}$$

7. How many individual atoms are present in 11.5 g of Na?

$$11.5 \text{ g} \times \frac{1 \text{ mol}}{23 \text{ g}} \times \frac{6.022 \times 10^{23} \text{ atoms}}{1 \text{ mol}} = 3.01 \times 10^{23} \text{ atoms}$$

8. What mass of gold contains as many atoms as 3.05 g of silver?

$$3.05 \text{ g Ag} \times \frac{1 \text{ mol}}{108 \text{ g}} = 0.0282 \text{ mol} \times \frac{197 \text{ g}}{1 \text{ mol}} = \boxed{5.56 \text{ g Au}}$$

9. Find the mass, in grams, of 4.00×10^{23} molecules of N_2 .

$$4 \times 10^{23} \text{ N}_2 \text{ molec} \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ molec}} \times \frac{28 \text{ g}}{1 \text{ mol}} = \boxed{18.6 \text{ g}}$$

10. What is the molar mass of each of the following compounds?

a. $\text{ZnSO}_4 \cdot 5\text{H}_2\text{O}$

$$5 \times 18 = 90$$

$$\begin{array}{r} 65 \\ 32 \\ 64 \\ + 90 \\ \hline 251 \text{ g/mol} \end{array}$$

b. KClO_2

$$107.3 \text{ g/mol}$$

c. $\text{Al}_2(\text{C}_2\text{O}_4)_3$

$$318.3 \text{ g/mol}$$

d. $\text{Na}_2\text{BH}_3\text{CO}_2$

$$104.3 \text{ g/mol}$$

e. P_4O_6

$$220.3 \text{ g/mol}$$

11. Answer the following questions about grain alcohol, $\text{C}_2\text{H}_6\text{O}$.

a. How many moles of each type of atom are in 2.55 mol?

$$2.55 \text{ mol} \times \frac{2 \text{ mol atoms}}{1 \text{ mol comp}} = 5.1 \text{ mol C} \quad 15.3 \text{ mol H} \quad 2.55 \text{ mol O}$$

b. What is the total number of moles of atoms?

$$23.0 \text{ mols}$$

c. What is the mass of each element in 2.55 mol?

$$5.1 \text{ mol C} \times \frac{12 \text{ g}}{\text{mol}} = 61.2 \text{ g C} \quad 15.3 \text{ mol H} \times \frac{1 \text{ g}}{\text{mol}} = 15.3 \text{ g H} \quad 2.55 \text{ mol O} \times \frac{16 \text{ g}}{\text{mol}} = 40.8 \text{ g O}$$

d. What is the total mass of 2.55 mol?

$$117.3 \text{ g}$$

12. What mass of each element is in 2.45 mol of boric acid (H_3BO_3)?

$$2.45 \text{ mol} \times \frac{3 \text{ mol H}}{1 \text{ mol}} \times \frac{1 \text{ g}}{\text{mol}} = 7.35 \text{ g H} \quad 2.45 \times \frac{3}{1} \times \frac{16 \text{ g}}{\text{mol}} = 117.6 \text{ g O} \quad (118 \text{ g})$$

$$2.45 \text{ mol} \times \frac{1 \text{ mol B}}{1 \text{ mol}} \times \frac{11 \text{ g}}{\text{mol}} = 26.95 \text{ g B} \quad (27.0 \text{ g})$$

13. You have 1.20×10^{22} O_2 molecules. Answer the following questions about them.

a. How many moles of O_2 do you have?

$$1.20 \times 10^{22} \times \frac{1 \text{ mol}}{6.022 \times 10^{23}} = 0.0199 \text{ mol}$$

b. How many moles of oxygen atoms do you have?

$$0.0199 \times 2 = 0.0398 \text{ mol}$$

c. What is the mass of oxygen molecules?

$$0.0199 \text{ mol O}_2 \times \frac{32 \text{ g}}{1 \text{ mol}} = 0.637 \text{ g}$$

d. What is the mass of oxygen atoms?

$$0.0398 \text{ mol O} \times \frac{16 \text{ g}}{1 \text{ mol}} = 0.637 \text{ g}$$

14. What is the percent composition of all of the elements in the following compounds?

a. $\text{C}_2\text{H}_6\text{O}$

C = 24	→ 52.1% C
H = 6	→ 13.0% H
O = $\frac{16}{46}$	→ 34.8% O

b. C_3H_6

C = 36	85.7% C
H = $\frac{6}{42}$	14.3% H

c. C_9H_{18}

C = 108	85.7% C
H = $\frac{18}{126}$	14.3% H

d. Na_2SO_4

Na 46	32.4% Na
S 32	22.5% S
O = $\frac{64}{142}$	45.1% O

e. $(\text{NH}_4)_2\text{CO}_3$

N = 28	29.1% N
H = 8	8.3% H
C = 12	12.5% C
O = $\frac{48}{96}$	50.0% O

15. What is the percent composition of NiO, if a sample of NiO with a mass of 10.3 g contains 8.1 g Ni and 2.2 g O?

$$\frac{8.1 \text{ g Ni}}{10.3 \text{ g NiO}} = 78.6\% \text{ Ni}$$

$$\frac{2.2 \text{ g O}}{10.3 \text{ g NiO}} = 21.4\% \text{ O}$$

16. What is the percent composition of a compound composed of 1.375 g of N and 3.935 g of O?

$$\frac{1.375 \text{ g}}{5.310 \text{ g}} = 25.9\% \text{ N}$$

$$\frac{3.935 \text{ g}}{5.310 \text{ g}} = 74.1\% \text{ O}$$

17. A sample of a compound has a mass of 4.86 g and is composed of silicon and oxygen. What is the percent composition if 2.27 g of the mass is silicon?

$$\frac{2.27\text{g}}{4.86\text{g}} = 46.71\% \text{ Si}$$

$$\frac{4.86 - 2.27}{4.86} = 53.3\% \text{ O}$$

18. What is the percent composition of all the elements in $\text{Fe}(\text{SCN})_2 \cdot 3\text{H}_2\text{O}$?

Fe	56	= 24.8% Fe	
S	64	= 28.3% S	2.65% H
C	24	= 10.6% C	21.2% O
N	28	= 12.4% N	
H	6		
O	+ 48		
	<hr/>		
	224		

19. What is the percentage of water in borax ($\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$)?

Na	46	
B	44	
O	112	
H ₂ O	180	
	<hr/>	
	382	

$$\frac{180}{382} = 47.1\% \text{ H}_2\text{O}$$

20. What is the percent composition of all of the elements in saccharin ($\text{C}_7\text{H}_5\text{SNO}_3$)?

C	84	45.9% C
H	5	2.73% H
S	32	17.5% S
N	14	7.65% N
O	+ 48	
	<hr/>	
	183	26.2% O

21. Convert the following quantities of elements to empirical formulas:

- a. 13.96 g of Fe and 8.02 g of S

$$13.96\text{g} \times \frac{1\text{mol}}{56\text{g}} = 0.249$$

$$8.02\text{g} \times \frac{1\text{mol}}{32\text{g}} = 0.250$$



- b. 1.88 mol of Sr and 3.76 mol of I

$$\frac{1.88}{1.88} = 1$$

$$\frac{3.76}{1.88} = 2$$



- c. 0.32 mol of K, 0.32 mol of Cl, and 0.96 mol of O

$$\frac{0.32}{0.32} = 1$$

$$\frac{0.32}{0.32} = 1$$

$$\frac{0.96}{0.32} = 3$$



- d. 126.90 g of I and 40.00 g of O

$$126.90\text{g} \times \frac{1\text{mol}}{127\text{g}} = 0.999 = 1$$

$$40\text{g} \times \frac{1\text{mol}}{16\text{g}} = 2.5 = 2.5$$



- e. 2.0 mol of Fe and 2.66 mol of O

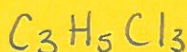
$$\frac{2.0}{2.0} = 1$$

$$\frac{2.66}{2.0} = 1.33 \times 3$$



f. 4.22 mol of C, 7.03 mol of H, and 4.22 mol of Cl

$$\begin{array}{ccc} \overset{1}{\times 3} & \overset{1.66}{\times 3} & \overset{1}{\times 3} \end{array}$$



22. What is the empirical formula of a compound that has the composition 63.2% oxygen and 36.8% nitrogen?

$$63.2g \times \frac{1 \text{ mol}}{16g} = 3.95 = 1.5 \times 2$$



$$36.8g \times \frac{1 \text{ mol}}{14g} = 2.63 = 1 \times 2$$

23. In an experiment it was found that 8.25 g of potassium combines with 6.75 g of O₂. What is the empirical formula of the compound?

$$8.25g \times \frac{1 \text{ mol}}{39g} = 0.212 = 1$$

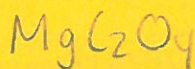


$$6.75g \times \frac{1 \text{ mol}}{32g} = 0.211 = 1$$

24. A compound is 21.6% Mg, 21.4% C, and 57.0% O. What is the empirical formula of the compound?

$$21.6g \times \frac{1}{24} = 0.9 = 1$$

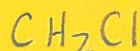
$$21.4g \times \frac{1}{12} = 1.78 = 2$$



$$57.0g \times \frac{1}{16} = 3.56 = 4$$

25. A compound is composed of 9.90 g of carbon, 1.65 g of hydrogen, and 29.3 g of chlorine. What is the empirical formula of the compound?

$$9.9 \times \frac{1}{12} = 0.825 = 1$$



$$1.65 \times \frac{1}{1} = 1.65 = 2$$

$$29.3 \times \frac{1}{35} = 0.837 = 1$$

26. A compound has the following composition: 20.0% C, 2.2% H, and 77.8% Cl. The molar mass of the compound is 545 g/mol. What is the molecular formula of the compound?

emp form

$$20g \times \frac{1}{12} = 1.67 = 1 \times 3 = 3$$

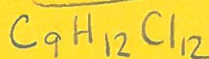
$$2.2g \times \frac{1}{1} = 2.2 = 1.33 \times 3 = 4$$

$$77.8g \times \frac{1}{35} = 2.22 = 1.33 \times 3 = 4$$

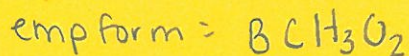


$$\begin{array}{r} \text{mm} = \\ 36 \\ 4 \\ \hline 140 \\ 180 \end{array}$$

$$\frac{545}{180} = 3$$



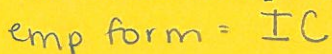
27. A compound has a composition of 18.7 % B, 20.7 % C, 5.15 % H, and 55.4 % O. Its molar mass is about 115 g/mol. What is the molecular formula of the compound?



mm = 58

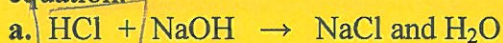
$$\frac{115}{58} = 2 \quad \text{B}_2\text{C}_2\text{H}_6\text{O}_4$$

28. A compound reported in 1982 has a molar mass of 834 g/mol. A 20.0 g sample of the compound contains 18.3 g of iodine and the remainder carbon. What is the molecular formula of the compound?



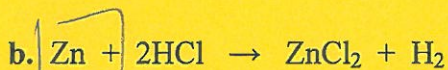
$$\frac{127}{12} \quad \frac{834}{139} = 6 \quad \text{I}_6\text{C}_6$$

29. Given the reaction amounts in moles, determine the limiting reactant in each balanced equation.



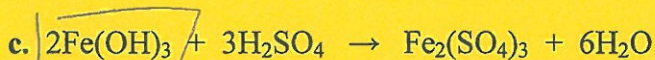
2.0 2.5 $2 \text{ mol HCl} \times \frac{1 \text{ mol NaCl}}{1 \text{ mol HCl}} = 2 \text{ mol NaCl}$ $2.5 \text{ mol NaOH} \times \frac{1 \text{ mol}}{1 \text{ mol}} = 2.5$

LR



2.5 6.0 $2.5 \text{ mol Zn} \times \frac{1 \text{ mol}}{1 \text{ mol}} = 2.5 \text{ mol ZnCl}_2$ $6 \text{ mol HCl} \times \frac{1 \text{ mol}}{2 \text{ mol}} = 3 \text{ mol}$

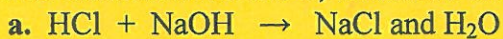
LR



4.0 6.5 $4.0 \text{ mol} \times \frac{1 \text{ mol}}{2 \text{ mol}} = 2 \text{ mol}$ $6.5 \text{ mol} \times \frac{1 \text{ mol}}{3 \text{ mol}} = 2.17$

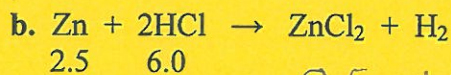
LR

30. For each reaction in #29, determine the amount in moles of excess reactant that remains.



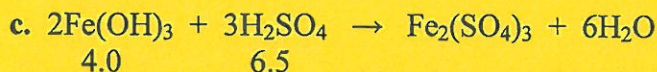
2.0 2.5

$0.5 \text{ mol NaCl} \times \frac{1 \text{ mol}}{1 \text{ mol}} = 0.5 \text{ mol NaOH}$



2.5 6.0

$$0.5 \text{ mol ZnCl}_2 \times \frac{2 \text{ mol}}{1 \text{ mol}} = 1 \text{ mol HCl}$$

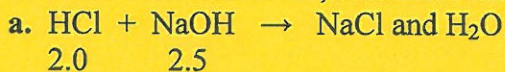


4.0

6.5

$$0.17 \text{ mol Fe}_2(\text{SO}_4)_3 \times \frac{3 \text{ mol}}{1 \text{ mol}} = 0.51 \text{ mol H}_2\text{SO}_4$$

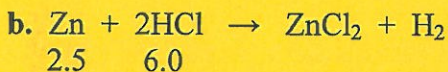
31. For each reaction in #29, determine the amount in moles of each product formed.



2.0 2.5

2 mol NaCl

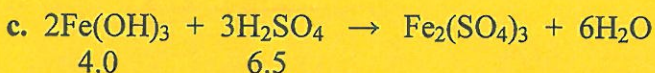
2 mol H₂O



2.5 6.0

2.5 mol ZnCl₂

2.5 mol H₂



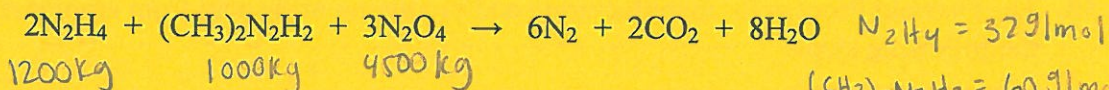
4.0

6.5

2 mol Fe₂(SO₄)₃

12 mol H₂O

32. The energy used to power one of the Apollo lunar missions was supplied by the following overall reaction:



1200 kg

1000 kg

4500 kg

N₂O₄ = 92 g/mol

N₂H₄ = 32 g/mol

(CH₃)₂N₂H₂ = 60 g/mol

For the phase of the mission when the lunar module ascended from the surface of the moon, a total of 1200. kg of N₂H₄ were available to react with 1000. kg of (CH₃)₂N₂H₂ and 4500. kg of N₂O₄.

a. For this portion of the flight, which of the allocated components was used up first?

$$4500 \text{ kg} \times \frac{1 \text{ mol}}{8.092 \text{ kg}} \times \frac{6 \text{ mol N}_2}{3 \text{ mol}} = 97826 \text{ mol}$$

$$1200 \text{ kg} \times \frac{1 \text{ mol}}{0.032 \text{ kg}} \times \frac{6 \text{ mol N}_2}{2 \text{ mol}} = 112500 \text{ mol N}_2$$

$$1000 \text{ kg} \times \frac{1 \text{ mol}}{0.060 \text{ kg}} \times \frac{6 \text{ mol N}_2}{1 \text{ mol}} = 100000 \text{ mol}$$

N₂O₄

18 g/mol

b. How much water, in kilograms, was put into the lunar atmosphere through this reaction?

$$4500 \text{ kg} \times \frac{1 \text{ mol}}{8.092 \text{ kg}} \times \frac{8 \text{ mol}}{3 \text{ mol N}_2\text{O}_4} \times \frac{0.018 \text{ kg}}{1 \text{ mol}} = 2.348 \times 10^3 \text{ kg H}_2\text{O}$$

33. Calculate the indicated quantity for each problem below:

a. Theoretical yield = 95g, actual yield = 65g, percent yield is 68%

b. Theoretical yield = 1.4 g, percent yield = 90%, actual yield is 1.26g

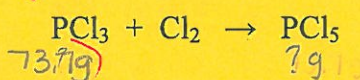
$$\frac{x}{1.4} = 0.9$$

c. Theoretical yield = 4.95g, actual yield = 4.75g, percent yield is 96.0%

$$\frac{4.75}{4.95}$$

d. Theoretical yield = 3.45g, percent yield = 48.0%, actual yield is 1.66g

34. The percentage yield for the reaction



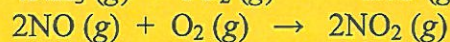
is 83.2%. What mass of PCl₅ is expected from the reaction of 73.7 g of PCl₃ with excess chlorine?

$$73.7\text{g PCl}_3 \times \frac{1\text{mol PCl}_3}{136\text{g}} \times \frac{1\text{mol}}{1\text{mol}} \times \frac{206\text{g}}{1\text{mol PCl}_5} = 112\text{g PCl}_5 \text{ w/ } 83.2\%$$

$$\frac{112\text{g}}{100\%} = \frac{x}{83.2\%}$$

$$\boxed{93.2\text{g}}$$

35. The Ostwald Process for manufacturing and producing nitric acid from ammonia consists of the following steps:



If the yield in each step is 94.0%, how many grams of nitric acid can be produced from 5.00 kg of ammonia?

$$5.00\text{ kg} = 5000\text{g} \times \frac{1\text{mol}}{17\text{g}} \times \frac{4\text{mol}}{4\text{mol}} = \frac{294\text{ mol NO}}{100} = \frac{x}{94\%}$$

$$x = 276.36\text{ mol}$$

$$276.36\text{ mol NO} \times \frac{2\text{mol NO}_2}{2\text{mol NO}} = 276.36\text{ mol NO}_2 \times (0.94) = 259.78\text{ mol NO}_2$$

$$259.78\text{ mol NO}_2 \times \frac{2\text{mol}}{3\text{mol}} \times \frac{63\text{g}}{1\text{mol}} = 10910.76\text{g} \times .94 = 10256.114\text{g}$$

$$\boxed{10300\text{g}}$$

36. How many moles of H_2SO_4 are present in 0.500 L of a 0.150 M H_2SO_4 solution?

$$\frac{0.150 \text{ mol}}{\text{L}} \times 0.500 \text{ L} = \boxed{0.0750 \text{ mol}}$$

37. What is the molarity of a solution composed of 5.85 g of potassium iodide, KI, dissolved in enough water to make 0.125 L of solution?

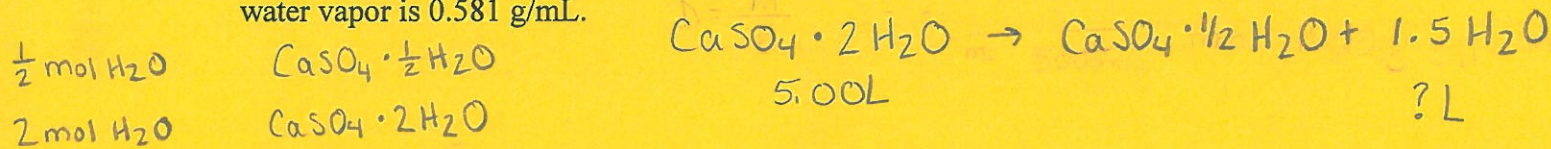
$$5.85 \text{ g} \times \frac{1 \text{ mol}}{166 \text{ g}} = 0.0352 \text{ mol}$$

$\begin{array}{r} 127 \\ + 39 \\ \hline 166 \end{array}$

$$\frac{0.0352 \text{ mol}}{0.125 \text{ L}} = \boxed{0.282 \text{ M}}$$

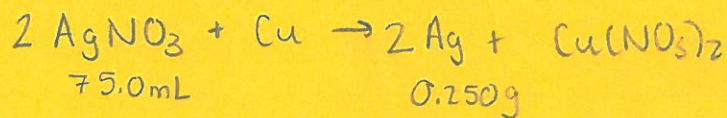
If you can solve the following problems, you have mastered Stoichiometry!

38. Builders and dentists must store plaster of Paris, $\text{CaSO}_4 \cdot \frac{1}{2} \text{H}_2\text{O}$, in airtight containers to prevent it from absorbing water vapor from the air and changing to gypsum, $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$. How many liters of water evolve when 5.00 L of gypsum are heated at 110°C to produce plaster of Paris? At 110°C , the density of $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ is 2.32 g/mL, and the density of water vapor is 0.581 g/mL.



$$5.00 \text{ L} \times \frac{2.32 \text{ g}}{1 \text{ mL}} \times \frac{1 \text{ mol}}{172 \text{ g}} \times \frac{1.5 \text{ mol H}_2\text{O}}{1 \text{ mol gypsum}} \times \frac{18 \text{ g}}{1 \text{ mol H}_2\text{O}} \times \frac{1 \text{ mL}}{0.581 \text{ g}} = \boxed{3.13 \text{ L H}_2\text{O}}$$

39. 75.0 mL of an AgNO_3 solution reacts with enough Cu to produce 0.250 g of Ag by single replacement. What is the molarity of the initial AgNO_3 solution if $\text{Cu}(\text{NO}_3)_2$ is the other product?



Ag	108
N	14
O	48
	170

$$0.250 \text{ g Ag} \times \frac{1 \text{ mol Ag}}{108 \text{ g}} \times \frac{2 \text{ mol AgNO}_3}{2 \text{ mol Ag}} = 0.00231 \text{ mol}$$

$$\frac{0.00231 \text{ mol}}{0.0750 \text{ L}} = \boxed{0.0309 \text{ M}}$$

40. Phosphate baking powder is a mixture of starch, sodium hydrogen carbonate, and calcium dihydrogen phosphate. When mixed with water, phosphate baking powder releases carbon dioxide gas, causing a dough or batter to bubble and rise.

$$\begin{array}{r} \text{C} = 12 \\ \text{O} = 32 \\ \hline 44 \end{array}$$



If 0.750 L of CO_2 is needed for a cake and each kilogram of baking powder contains 168 g of NaHCO_3 , how many grams of baking powder must be used to generate this amount of CO_2 ? The density of CO_2 at baking temperature is about 1.20 g/L.

1 kg powder = 168 g NaHCO_3

? g powder

$$0.750 \text{ L CO}_2 \times \frac{1.20 \text{ g CO}_2}{1 \text{ L CO}_2} \times \frac{1 \text{ mol CO}_2}{44 \text{ g}} \times \frac{2 \text{ mol NaHCO}_3}{2 \text{ mol CO}_2} \times \frac{84 \text{ g NaHCO}_3}{1 \text{ mol NaHCO}_3} \times \frac{1 \text{ kg powder}}{168 \text{ g NaHCO}_3} \times \frac{1000 \text{ g}}{1 \text{ kg}}$$

$$= 10.2 \text{ g baking powder}$$