Key

Stoichiometry Review

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

a. 1.00 mol of Cu

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

b. 0.50 mol of S

$0.5 \text{ mol S} \times \frac{32g}{1 mol} = 16g$

c. 6.02×10^{23} atoms of Ca

$6.02 \times 10^{23} \text{ atoms} \times \frac{1 mol}{6.02 \times 10^{23} \text{ atoms}} \times \frac{40g}{1 mol} = 40g$

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

a. 32.1 mol of sulfur

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

b. 32.1 g of sulfur

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

c. 32.0 g of oxygen

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

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

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

$\frac{0.251g}{0.00232 mol} = 107.97 g/mol = \boxed{Ag}$

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

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

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

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

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

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

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

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

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

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

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

$4 \times 10^{23} N_2 \text{ molec} \times \frac{1 mol}{6.022 \times 10^{23} \text{ molec}} \times \frac{28g}{1 mol} = \boxed{18.6g}$

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

a. $ZnSO_4{\cdot}5H_2O$

5×18=90

65
32
64
+ 90

251 g/mol

b. $KClO_2$

107 g/mol

c. $Al_2(C_2O_4)_3$

318 g/mol

d. $Na_2BH_3CO_2$

104 g/mol

e. P_4O_6

220 g/mol

11. Answer the following questions about grain alcohol, C_2H_6O.

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

2.55 mol × (2 mol C atoms / 1 mol cmpd) = 5.1 mol C 15.3 mol H 2.55 mol O

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

23.0 mols

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

5.1 mol C × 12 g/mol = 61.2 g C 15.3 mol H × 1 g/1 mol = 15.3 g H 2.55 mol O × 16 g/1 mol = 40.8 g O

d. What is the total mass of 2.55 mol?

117.3 g

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

2.45 mol × (3 mol H / 1 mol) × (1 g / 1 mol) = 7.35 g H 2.45 × 3/1 × 16 g/mol = 117.6 g O (118 g)

2.45 mol × (1 mol B / 1 mol) × (11 g / mol) = 26.95 g B (27.0 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 x 2 = 0.0398 mol

c. What is the mass of oxygen molecules?

$0.0199 \text{ mol } O_2 \times \frac{32g}{1 mol} \rightarrow 0.637g$

d. What is the mass of oxygen atoms?

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

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

a. C_2H_6O

C = 24 → 52.1% C
H = 6 → 13.0% H
O = 16 → 34.8% O
46

b. C_3H_6

C = 36 85.7% C
H = + 6 14.3% H
42

c. C_9H_{18}

C = 108 85.7% C
H = 18 14.3% H
126

d. Na_2SO_4

Na 46 32.4% Na
S 32 22.5% S
O = 64 45.1% O
142

e. $(NH_4)_2CO_3$

N = 28 29.1% N
H = 8 8.33% H
C = 12 12.5% C
O = 48 50.0% O
96

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?

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

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

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

1.375g
+ 3.935g
5.310

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

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

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?

$\frac{2.27g}{4.86g}$ = 46.7% Si

4.86 − 2.27 = 2.59

$\frac{2.59}{4.86}$ = 53.3% O

18. What is the percent composition of all the elements in $Fe(SCN)_2 \cdot 3H_2O$?

Fe 56 = 24.8% Fe
S 64 = 28.3% S
C 24 = 10.6% C
N 28 = 12.4% N
H 6
O + 48
226

2.65% H
21.2% O

19. What is the percentage of water in borax ($Na_2B_4O_7 \cdot 10H_2O$)?

Na 46
B 44
O 112
H_2O 180
382

$\frac{180}{382}$ = 47.1% H_2O

20. What is the percent composition of all of the elements in saccharin ($C_7H_5SNO_3$)?

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

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

a. 13.96 g of Fe and 8.02 g of S

13.96g × $\frac{1 mol}{56g}$ = 0.249

8.02g × $\frac{1 mol}{32g}$ = 0.250

FeS

b. 1.88 mol of Sr and 3.76 mol of I

1.88 = 1 ; 1.88 = 2

SrI_2

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

= 1 ; = 1 ; 0.32 = 3

$KClO_3$

d. 126.90 g of I and 40.00 g of O

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

40g × $\frac{1 mol}{16g}$ = 2.5 = 2.5

I_2O_5

e. 2.0 mol of Fe and 2.66 mol of O

= 1 × 3 ; = 1.33 × 3

Fe_3O_4

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

= 1 ×3   = 1.66 ×3   = 1 ×3

$C_3H_5Cl_3$

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

63.2g × 1mol/16g = 3.95 = 1.5×2

36.8g × 1mol/14g = 2.63 = 1 ×2

N_2O_3

23. In an experiment it was found that 8.25 g of potassium combines with 6.75 g of O_2. What is the empirical formula of the compound?

8.25g × 1mol/39g = 0.212 = 1

6.75g × 1mol/32g = 0.211 = 1

KO_2

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

21.6g × /24 = 0.9 = 1

21.4g × /12 = 1.78 = 2

57.0g × /16 = 3.56 = 4

MgC_2O_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 × /12 = 0.825 = 1

1.65 × /1 = 1.65 = 2

29.3 × /35 = 0.837 = 1

CH_2Cl

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 × /12 = 1.67 = 1 ×3 = 3

2.2g × /1 = 2.2 = 1.33 ×3 = 4

77.8g × /35 = 2.22 = 1.33 ×3 = 4

$C_3H_4Cl_4$

mm = 36 + 4 + 140 = 180

545/180 = 3

$C_9H_{12}Cl_{12}$

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?

emp form = BCH_3O_2

mm = 58

$\frac{115}{58} = 2$ $B_2C_2H_6O_4$

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?

emp form = IC

127 + 12 = 139 $\frac{834}{139} = 6$ I_6C_6

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

a. HCl + NaOH → NaCl and H_2O
2.0 2.5

LR (HCl)

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

b. Zn + 2HCl → $ZnCl_2$ + H_2
2.5 6.0

LR (Zn)

2.5 mol Zn × $\frac{1 mol}{1 mol}$ = 2.5 mol $ZnCl_2$ 6 mol HCl × $\frac{1 mol}{2 mol}$ = 3 mol

c. $2Fe(OH)_3$ + $3H_2SO_4$ → $Fe_2(SO_4)_3$ + $6H_2O$
4.0 6.5

LR ($2Fe(OH)_3$)

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

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

a. HCl + NaOH → NaCl and H_2O
2.0 2.5

0.5 mol NaCl × $\frac{1 mol}{1 mo}$ = **0.5 mol NaOH**

b. $Zn + 2HCl \rightarrow ZnCl_2 + H_2$
2.5   6.0

0.5mol $ZnCl_2$ × 2mol / 1mol = 1mol HCl

c. $2Fe(OH)_3 + 3H_2SO_4 \rightarrow Fe_2(SO_4)_3 + 6H_2O$
4.0   6.5

0.17 mol $Fe_2(SO_4)_3$ × 3mol / 1mol = 0.51mol H_2SO_4

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

a. $HCl + NaOH \rightarrow NaCl$ and H_2O
2.0   2.5

2 mol NaCl
2mol H_2O

b. $Zn + 2HCl \rightarrow ZnCl_2 + H_2$
2.5   6.0

2.5mol $ZnCl_2$
2.5mol H_2

c. $2Fe(OH)_3 + 3H_2SO_4 \rightarrow Fe_2(SO_4)_3 + 6H_2O$
4.0   6.5

2 mol $Fe_2(SO_4)_3$
12 mol H_2O

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

N_2O_4 = 92 g/mol
N_2H_4 = 32 g/mol
$(CH_3)_2N_2H_2$ = 60 g/mol

$$2N_2H_4 + (CH_3)_2N_2H_2 + 3N_2O_4 \rightarrow 6N_2 + 2CO_2 + 8H_2O$$

1200kg   1000kg   4500 kg

For the phase of the mission when the lunar module ascended from the surface of the moon, a total of 1200. kg of N_2H_4 were available to react with 1000. kg of $(CH_3)_2N_2H_2$ and 4500. kg of N_2O_4.

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

4500kg × 1mol / 0.092kg × 6mol N_2 / 3mol = 97826mol

1200kg × 1mol / 0.032kg × 6mol N_2 / 2mol = 112500 mol N_2

1000kg × 1mol / 0.060kg × 6mol N_2 / 1mol = 100000 mol

N_2O_4

18g/mol

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

4500 kg × 1mol / 0.092kg × 8 mol / 3 mol N_2O_4 × 0.018kg / 1mol = 2.348×10^3 kg H_2O

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

$$PCl_3 + Cl_2 \rightarrow PCl_5$$

73.7g ?g

is 83.2%. What mass of PCl_5 is expected from the reaction of 73.7 g of PCl_3 with excess chlorine?

$73.7g\ PCl_3 \times \frac{1mol\ PCl_3}{136g} \times \frac{1mol}{1mol} \times \frac{206g}{1mol\ PCl_5} = 112g\ PCl_5$ w/ 83.2%

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

93.2g

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

$$4NH_3\ (g) + 5O_2\ (g) \rightarrow 4NO\ (g) + 6H_2O\ (g)$$
$$2NO\ (g) + O_2\ (g) \rightarrow 2NO_2\ (g)$$
$$3NO_2\ (g) + H_2O\ (g) \rightarrow 2HNO_3\ (aq) + NO\ (g)$$

$HNO_3 = 63$

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

$x = 276.36mol$

$276.36mol\ NO \times \frac{2\ mol\ NO_2}{2mol\ NO} = 276.36\ mol\ NO_2 \times (0.94) = 259.78\ mol\ NO_2$

$259.78\ mol\ NO_2 \times \frac{2mol}{3mol} \times \frac{63g}{1mol} = 10910.76g \times .94 = 10256.114\ g$

10300 g

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

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

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? KI

127 + 39 = 166

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

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

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

38. Builders and dentists must store plaster of Paris, $CaSO_4 \cdot \frac{1}{2}H_2O$, in airtight containers to prevent it from absorbing water vapor from the air and changing to gypsum, $CaSO_4 \cdot 2H_2O$. 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 $CaSO_4 \cdot 2H_2O$ is 2.32 g/mL, and the density of water vapor is 0.581 g/mL.

$\frac{1}{2}$ mol H_2O — $CaSO_4 \cdot \frac{1}{2}H_2O$

2 mol H_2O — $CaSO_4 \cdot 2H_2O$

$$CaSO_4 \cdot 2H_2O \rightarrow CaSO_4 \cdot \tfrac{1}{2}H_2O + 1.5\,H_2O$$

5.00L → ?L

$$5.00L \times \frac{2.32g}{1mL} \times \frac{1mol}{172g\ CaSO_4 \cdot 2H_2O} \times \frac{1.5mol\ H_2O}{1mol\ gypsum} \times \frac{18g}{1mol\ H_2O} \times \frac{1mL}{0.581g} = \boxed{3.13L\ H_2O}$$

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 $Cu(NO_3)_2$ is the other product?

Ag 108, N 14, O + 48 = 170

$$2AgNO_3 + Cu \rightarrow 2Ag + Cu(NO_3)_2$$

75.0mL → 0.250g

$$0.250g\ Ag \times \frac{1mol\ Ag}{108g} \times \frac{2mol\ AgNO_3}{2mol\ Ag} = 0.00231\,mol$$

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

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.

C = 12
O = 32
44

$2NaHCO_3\ (aq) + Ca(H_2PO_4)_2\ (aq) \rightarrow 2Na_2HPO_4\ (aq) + CaHPO_4\ (aq) + 2CO_2\ (g) + 2H_2O\ (l)$

0.750L

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.

Na 23
H 1
C 12
O + 48
84

1 kg powder = 168 g $NaHCO_3$? g powder

$$0.750\,L\,CO_2 \times \frac{1.20\,g\,CO_2}{1\,L\,CO_2} \times \frac{1\,mol\,CO_2}{44\,g} \times \frac{2\,mol\,NaHCO_3}{2\,mol\,CO_2} \times \frac{84\,g\,NaHCO_3}{1\,mol\,NaHCO_3} \times \frac{1\,kg\,powder}{168\,g\,NaHCO_3} \times \frac{1000\,g}{1\,kg}$$

= 10.2 g baking powder