

**Chapter 3 (exercises)****Q1. Sample exercise 3.7 page 90**

Without using calculator, arrange the following samples in order to increasing number of carbon atoms:

12 g  $^{12}\text{C}$  , 1 mol  $\text{C}_2\text{H}_2$  ,  $9 \times 10^{23}$  molecules of  $\text{CO}_2$

Answer:

12 g of  $^{12}\text{C}$  = 1 mole of C =  $6.03 \times 10^{23}$  number of carbons

1 mole of  $\text{C}_2\text{H}_2$  =  $2 \times 6.03 \times 10^{23} = 12.06 \times 10^{23}$  carbon atoms (because we have 2 atoms in  $\text{C}_2\text{H}_2$ )

$\text{CO}_2$  contain  $9 \times 10^{23}$  carbon

The order of increasing carbon atoms is  $\text{C}_2\text{H}_2 > \text{CO}_2 > ^{12}\text{C}$

**Q2. Practice exercise page 90**

Without using calculator, arrange the following samples in order of increasing number of oxygen atoms:

1 mole of  $\text{H}_2\text{O}$ , 1 mole of  $\text{CO}_2$  ,  $3 \times 10^{23}$  molecules  $\text{O}_3$  .

Answer:

1 mole  $\text{H}_2\text{O}$  contain 1 mole oxygen =  $6.03 \times 10^{23}$  number of oxygen atoms in  $\text{H}_2\text{O}$

1 mole of  $\text{CO}_2$  contain 2 moles of oxygen =  $2 \times 6.03 \times 10^{23}$  number of oxygen atoms in  $\text{CO}_2$

$\text{O}_3$  molecule contain  $3 \times 3 \times 10^{23}$  oxygen atoms =  $9.0 \times 10^{23}$

The order is:  $\text{H}_2\text{O} < \text{O}_3 < \text{CO}_2$

**Q3. Sample exercise 3.8 page 90**

Calculate the number of H atoms in 0.350 mole of  $\text{C}_6\text{H}_{12}\text{O}_6$

Answer:

1 mole of  $\text{C}_6\text{H}_{12}\text{O}_6$  contain  $6.03 \times 10^{23}$  molecules of  $\text{C}_6\text{H}_{12}\text{O}_6$

0.250 mole of  $\text{C}_6\text{H}_{12}\text{O}_6$  contain (0.250 mole)  $(6.03 \times 10^{23}) / (1 \text{ mole}) = 2.11 \times 10^{23}$  atoms of  $\text{C}_6\text{H}_{12}\text{O}_6$

Each molecule of  $\text{C}_6\text{H}_{12}\text{O}_6$  contain 12 H atoms

$2.11 \times 10^{23}$  atoms of  $C_6H_{12}O_6$  contain  $(12 \text{ H atoms}) \times (2.11 \times 10^{23}) / 1 = 2.53 \times 10^{24}$  H atoms

**Q4. Practice exercise page 91**

How many oxygen atoms are in a) 0.25 mole of  $Ca(NO_3)_2$ , b) 1.50  $Na_2CO_3$

Answer:

$$\begin{aligned} \text{a) Number of molecules of } Ca(NO_3)_2 &= (0.25 \text{ mole of } Ca(NO_3)_2) \times (6.03 \times 10^{23}) / (1 \text{ mole of } Ca(NO_3)_2) \\ &= 1.51 \times 10^{23} \text{ number of } Ca(NO_3)_2 \text{ molecule} \end{aligned}$$

Each 1 molecule of  $Ca(NO_3)_2$  contain 6 oxygen atoms

$$\text{Number of oxygen atoms} = (1.51 \times 10^{23}) \times (6) / (1) = 9.06 \times 10^{23}$$

$$\begin{aligned} \text{b) number of molecules of } Na_2CO_3 &= (1.50 \text{ mole of } Na_2CO_3) \times (6.03 \times 10^{23}) / (1 \text{ mole of } Na_2CO_3) \\ &= 9.05 \times 10^{23} \end{aligned}$$

Each 1 molecule of  $Na_2CO_3$  contain 3 atoms of oxygen

$$\text{Number of oxygen atoms} = (9.05 \times 10^{23}) \times (3) / 1 = 27.1 \times 10^{23}$$

**Q5. Sample exercise 3.9 page 92**

What is the mass in grams of 1.000 mole glucose ( $C_6H_{12}O_6$ )?

Answer:

We are given a chemical formula  $C_6H_{12}O_6$  and asked for the determination its molar mass.

$$6 \text{ C atoms} = 6(12.0 \text{ amu}) = 72.0 \text{ amu}$$

$$12 \text{ H atoms} = 12(1.0 \text{ amu}) = 12 \text{ amu}$$

$$6 \text{ O atoms} = 6(16.0 \text{ amu}) = 96.0 \text{ amu}$$

$$\begin{array}{r} \text{Total} \\ \hline \end{array} = 180.0 \text{ amu}$$

Glucose has a formula weight = 180.0 amu

Glucose has a mass of = 180.0 g

Glucose has a molar mass of = 180.0 mol/g

**Q6. Practice exercise page 92**

Calculate the molar mass of  $\text{Ca}(\text{NO}_3)_2$ .

$$1 \text{ Ca atom} = 1(40 \text{ amu}) = 40 \text{ amu}$$

$$2 \text{ N atoms} = 2(14 \text{ amu}) = 28 \text{ amu}$$

$$6 \text{ O atoms} = 6(16 \text{ amu}) = 96 \text{ amu}$$

$$\text{Molar mass of } \text{Ca}(\text{NO}_3)_2 = 164 \text{ amu}$$

**Q.7** Sample exercise 3.10 page 93

Calculate the number of molar mass of glucose in 5.380 g of  $\text{C}_6\text{H}_{12}\text{O}_6$ .

Answer:

$$\text{Molar mass of } \text{C}_6\text{H}_{12}\text{O}_6 = 180 \text{ g/mol}$$

$$1 \text{ mol of glucose} = 180 \text{ g}$$

$$\text{Number of moles} = \text{mass} / \text{molar mass} = (5.380 \text{ g}) / (180 \text{ g/mol}) = 0.02989 \text{ mol}$$

**Q.8** Practice exercise page 93

How many moles of  $\text{NaHCO}_3$  are in 508 g of  $\text{NaHCO}_3$ .

Answer:

$$\text{Number of moles of } \text{NaHCO}_3 = \text{mass} / \text{molar mass} = (508 \text{ g}) / (84 \text{ g/mol}) = 6.05 \text{ mol}$$

**Q9.** Practice exercise page 93

What is the mass, in gram, a) 6.33 mol of  $\text{NaHCO}_3$  and b)  $3.0 \times 10^{-5}$  mole of sulfuric acid

Answer:

$$\text{a) mole of } \text{NaHCO}_3 = \text{mass} / \text{molar mass}$$

$$6.33 \text{ mole} = \text{mass} / (84 \text{ g/mol}) = 532 \text{ g}$$

$$\text{b) mole of } \text{H}_2\text{SO}_4 = \text{mass} / \text{molar mass}$$

$$3.0 \times 10^{-5} \text{ mole} = \text{mass} / (98 \text{ g/mol}) \quad \text{mass} = 2.9 \times 10^{-3} \text{ g}$$

**Q10.** Practice exercise page 93

a) How many nitric acid molecules are in 4.20 g  $\text{HNO}_3$ ? b) How many  $\text{O}_2$  atoms are in the sample?

Answer:

$$\text{a) Mole of HNO}_3 = (4.20 \text{ g}) / (63 \text{ g/mol}) = 0.067$$

1 mole of HNO<sub>3</sub> contain  $6.03 \times 10^{23}$  molecules

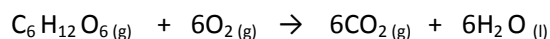
$$0.067 \text{ mole of HNO}_3 = (0.067 \text{ mol})(6.03 \times 10^{23} \text{ molecules}) / (1 \text{ mol}) = 0.402 \times 10^{23} \text{ molecules}$$

b) 1 molecule HNO<sub>3</sub> contain 3 O atom

$$\text{Oxygen in sample contain} = (0.402 \times 10^{23}) (3) / (1) = 1.2 \times 10^{23} \text{ molecules.}$$

**Q11. Sample exercise 3.16 page 100**

How many grams of water are produced in the oxidation of 1.00 g glucose (C<sub>6</sub>H<sub>12</sub>O<sub>6</sub>)?



Answer:

$$\text{Mole of C}_6\text{H}_{12}\text{O}_6 = (1 \text{ g}) / (180.1 \text{ g/mol}) = 0.00556$$

1 mole of glucose forms 6 mole CO<sub>2</sub>

$$\begin{aligned} \text{Mole of H}_2\text{O} &= (0.00556 \text{ mol glucose}) (6 \text{ mol of CO}_2) / 1 \text{ mol of glucose} \\ &= 0.033 \end{aligned}$$

$$\text{Grams of H}_2\text{O} = 0.033 \text{ mole} \times (18 \text{ g/mol}) = 0.6 \text{ g}$$

**Q12. Practice exercise page 101**

The decomposition of KClO<sub>3</sub> to form oxygen  $2\text{KClO}_3 \rightarrow 2\text{Cl} + 3\text{O}_2(\text{g})$ . How many grams of O<sub>2</sub> can

Be prepared from 4.50 g KClO<sub>3</sub>?

Answer:

$$\text{Mole of KClO}_3 = (4.50 \text{ g}) / (122.5) = 0.037$$

$$\text{Mole of O}_2 = (0.037 \text{ mole KClO}_3) (3 \text{ mol O}_2) / (2 \text{ mole KClO}_3) = 0.0551$$

$$\text{Grams of O}_2 = (0.0551 \text{ mole O}_2) \times 16 = 0.88$$

**Q13. Sample exercise 3.17 page 101**

The lithium hydroxide reacts with CO<sub>2</sub> to form solid lithium carbonate and liquid water. How many

Grams of CO<sub>2</sub> can be absorbed by 1 g of LiOH?

Answer:

$$\text{Moles of LiOH} = (1 \text{ g}) / (23.95 \text{ g/mol}) = 0.042$$

2 mole LiOH form 1 mole CO<sub>2</sub>

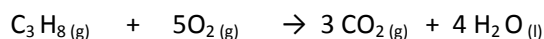
$$\begin{aligned} 0.042 \text{ mole of LiOH form} &= (0.042 \text{ mol LiOH}) \times (1 \text{ mol CO}_2) / (2 \text{ mol LiOH}) \\ &= 0.021 \text{ mole CO}_2 \end{aligned}$$

$$\text{Grams of CO}_2 = (0.021 \text{ mole}) \times (44.01 \text{ g/mol}) = 0.919 \text{ g}$$

**Q14.** Practice exercise page 102

Propane C<sub>3</sub>H<sub>8</sub>, is a common fuel used for cooking heating. What mass of O<sub>2</sub> is consumed in the combustion of 1.0 g of propane?

Answer:



$$\text{Mole of C}_3\text{H}_8 = (1 \text{ g}) / (39 \text{ g/mol}) = 0.023$$

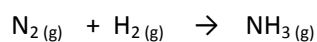
1 mole of C<sub>3</sub>H<sub>8</sub> needs 5 mole of O<sub>2</sub>

$$\text{Moles of O}_2 = (0.023 \text{ mole C}_3\text{H}_8) \times (5 \text{ mol O}_2) / (1 \text{ mol C}_3\text{H}_8) = 0.1115$$

$$\text{Mass of O}_2 = (0.1115 \text{ mole of O}_2) \times (32 \text{ g/mol}) = 3.68$$

**Q 15.** Sample exercise 3.18 page 104

The important commercial process for converting N<sub>2</sub> from the air into nitrogen containing compounds is based on the reaction of N<sub>2</sub> and H<sub>2</sub> to form NH<sub>3</sub>.



How many moles of NH<sub>3</sub> can be formed from 3.0 mole N<sub>2</sub> and 6.0 mole H<sub>2</sub>?

Answer:

1 mole of N<sub>2</sub> needs 3.0 mole of H<sub>2</sub>

$$\text{Mole of H}_2 = (3.0 \text{ mol}) \times (3.0 \text{ mol H}_2) / (1 \text{ mol N}_2) = 9.0 \text{ mole}$$

$$\text{Mole of NH}_3 = (6 \text{ mol H}_2) \times (2 \text{ mol NH}_3 / 3 \text{ mol H}_2) = 4.0 \text{ mol NH}_3$$

	$\text{N}_2$	+	$3\text{H}_2$	$\rightarrow$	$2\text{NH}_3$
Initial quantities	3.0 mole		6.0 mole		0 mole
Change (reaction)	- 2 mole		-6.0 mole		+ 4.0 mole
Final quantities	1.0 mole		0 mole		4.0 mole

**Q16. Practice exercise page 104**

Consider the reaction  $2\text{Al}_{(s)} + 3\text{Cl}_{2(g)} \rightarrow 2\text{AlCl}_{3(s)}$ . A mixture of 1.5 mole of Al and 3.0 mole of  $\text{Cl}_2$  to react.

- Which is the limiting reaction?
- How many moles of the  $\text{AlCl}_3$  are formed?
- How many moles of the excess reactant at the end of reaction?

**Answer:**

2 moles of Al needs 3 moles of  $\text{Cl}_2$

1.5 mole of Al needs  $\text{Cl}_2 = (1.5 \text{ mol Al}) \times (3 \text{ mol Cl}_2) / (2 \text{ mol Al}) = 2.25 \text{ mol of Cl}_2$

Al is a limiting reaction or limiting reagent.

$\text{Cl}_2$  is the excess reaction or excess reagent.

Moles of  $\text{AlCl}_3$  formed =  $(2.25 \text{ mol Cl}_2) \times (2 \text{ mol AlCl}_3) / (3 \text{ mol Cl}_2) = 1.5 \text{ mol AlCl}_3$

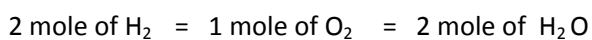
	$2\text{Al}$	+	$3\text{Cl}_2$	$\rightarrow$	$2\text{AlCl}_3$
Initial quantities	1.5 mole		3.0 mole		0 mole
Change (reaction)	- 1.5 mole		- 2.25 mole		+ 1.5 mole
Final quantities	0 mole		0.75 mole		1.5 mole

**Q17. Sample exercise 3.19 page 104**

Consider the following reaction that occur in the fuel cell  $2\text{H}_{2(g)} + \text{O}_{2(g)} \rightarrow 2\text{H}_2\text{O}$

Suppose a fuel cell is set with 150 g of  $\text{H}_2$  gas and 1500 g of  $\text{O}_2$  gas. How many grams of water can be formed?

Answer:



$$\text{Mole H}_2 = (150 \text{ g H}_2) \times (1 \text{ mol H}_2 / 2.0 \text{ g}) = 75 \text{ mol H}_2$$

$$\text{Mole O}_2 = (1500 \text{ g}) / (32 \text{ g/mol}) = 47 \text{ mol O}_2$$

$$\text{Mole of O}_2 = (75 \text{ mol H}_2) \times (1 \text{ mol O}_2) / (2 \text{ mol H}_2) = 37.5 \text{ mol O}_2 \text{ needs for reaction}$$

H<sub>2</sub> is the limiting reagent

$$\text{Mole of H}_2\text{O} = (75 \text{ mol H}_2) \times (2 \text{ mol H}_2\text{O}) / (2 \text{ mol H}_2) = 75 \text{ mol H}_2\text{O}$$

$$\text{Mass of H}_2\text{O} = (75 \text{ mol}) \times (18 \text{ g/mol}) = 1400 \text{ g of water}$$

**Q18. Practice exercise page 105**

A strip of zinc metal with mass 2.00 g is placed in an aqueous solution containing 2.50 g of AgNO<sub>3</sub>,

the reaction is  $\text{Zn}_{(s)} + 2 \text{AgNO}_{3(s)} \rightarrow 2 \text{Ag}_{(s)} + \text{Zn}(\text{NO})_{2(aq)}$ .

- Which of the reaction is limiting?
- How many grams of Ag will form?
- How many grams of Zn(NO)<sub>2</sub> will form?
- How many grams of excess reagent will be left at the end of reaction?

Answer:

$$\text{a) } 1 \text{ mol Zn} = 2 \text{ mol AgNO}_3 = 2 \text{ mol Ag} = 1 \text{ mol Zn}(\text{NO})_2$$

$$\text{mole of Zn} = (2.00 \text{ g}) / (65.39 \text{ g/mol}) = 0.031$$

$$\text{mole of AgNO}_3 = (2.50 \text{ g}) / (169.89 \text{ g/mol}) = 0.015$$

AgNO<sub>3</sub> is the limiting reagent

$$\text{b) } 2 \text{ mol AgNO}_3 = 2 \text{ mol Ag}$$

$$\text{mole of Ag} = (0.015 \text{ mol AgNO}_3) \times (2 \text{ mol Ag}) / (2 \text{ mol AgNO}_3) = 0.015 \text{ mole}$$

$$\text{gram of Ag} = (0.015 \text{ mole}) \times (107.89 \text{ g/mol}) = 1.62 \text{ g}$$

$$\text{c) } 2 \text{ mol of Ag} = 1 \text{ mole Zn}(\text{NO}_3)_2$$

$$\text{mole of Zn}(\text{NO})_2 = (0.015 \text{ mol Ag}) \times (1 \text{ mol Zn}(\text{NO})_2) / (2 \text{ mol Ag}) = 0.0075$$

$$\text{gram of Zn(NO)}_2 = (0.0075 \text{ mole}) \times (189.39 \text{ g/mol}) = 1.4 \text{ g}$$

$$\text{d) excess of reagent Zn} = 0.031 - (0.015/2) = 0.0235 \text{ mol}$$

$$\text{gram of Zn} = 0.0235 \times 65.39 = 1.53 \text{ g}$$

**Q 19. Practice page 107**

Imagine that you working on ways to improve the process by which iron ore containing  $\text{Fe}_2\text{O}_3$  is

converted into Fe. The reaction is  $\text{Fe}_2\text{O}_{3(s)} + 3\text{CO}_{(g)} \rightarrow 2\text{Fe}_{(s)} + 3\text{CO}_{2(g)}$ .

a) If you start with 150 g of  $\text{Fe}_2\text{O}_3$  as the limiting reagent, what is the theoretical yield of Fe?

b) If the actual yield of Fe in your test was 87.9 g, what was the percentage yield?

Answer:

$$\text{a) } 1 \text{ mol Fe}_2\text{O}_3 = 3 \text{ mol CO} = 2 \text{ mol Fe} = 3 \text{ mol CO}_2$$

$$\text{mole of Fe}_2\text{O}_3 = (150 \text{ g}) / (159.694 \text{ g/mol}) = 0.94 \text{ mol}$$

$$\text{mole of Fe} = (0.94 \text{ mol Fe}_2\text{O}_3) \times (2 \text{ mol Fe}) / (1 \text{ mol /g}) = 1.88$$

$$\text{gram of Fe} = (1.88 \text{ mol}) \times (55.847 \text{ g/mol}) = 105 \text{ g}$$

$$\text{b) Theoretical yield} = (87.9 \text{ g} / 105 \text{ g}) \times 100 = 83\%$$

Exercise page 109

**3.33**

Calculate the following quantities

- Mass in gram of 0.105 moles sucrose  $\text{C}_{12}\text{H}_{22}\text{O}_{11}$ .
- Mole of  $\text{Zn(NO)}_3$  in 143.50 g of this substance.
- Number of molecules in  $1.0 \times 10^{-6}$  mole of  $\text{CH}_3\text{CH}_2\text{OH}$ .
- Number of N atoms in 0.41 mole  $\text{NH}_3$ .

Answer:

$$\text{a) molar mass of C}_{12}\text{H}_{22}\text{O}_{11} = 12 \times 12 + 22 \times 1 + 11 \times 16 = 342$$

$$\text{grams of sucrose} = 0.105 \text{ mole} \times 342 = 35.91 \text{ g}$$



b) molar mass of  $\text{Zn}(\text{NO})_2 = 65.39 + 2 \times 14 + 2 \times 16 = 125.39$

$$\text{Mole of Zn}(\text{NO})_2 = (143.509 \text{ g}) / (125.39 \text{ g/mol}) = 1.145$$

c)  $1.0 \times 10^{-6}$  moles contain  $\text{CH}_3\text{CH}_2\text{OH}$  molecules =  $(6.03 \times 10^{23} \text{ molecules})(1.0 \times 10^{-6}) / (1 \text{ mole})$   
 $= 6.03 \times 10^{17}$  molecules of  $\text{CH}_3\text{CH}_2\text{OH}$ .

d) molecules on  $\text{NH}_3$  in 0.410 =  $(6.03 \times 10^{23})(0.410 \text{ mol NH}_3) / (1 \text{ mol NH}_3)$   
 $= 2.4723 \times 10^{23}$  molecules of  $\text{NH}_3$

1 molecule of  $\text{NH}_3 = 1$  atom of N

$$2.4723 \times 10^{23} \text{ molecules of NH}_3 \times (1 \text{ N} / 1 \text{ NH}_3) = 2.4723 \times 10^{23} \text{ number of atoms of N}$$

### **3.39**

A sample of glucose contains  $1.250 \times 10^{21}$  carbon atom.

a) How many atoms of hydrogen does it contain?

b) How many molecules of glucose does it contain?

c) How many moles of glucose does it contain?

d) What is the mass of this sample in grams?

Answer:

a) 6 mol of C = 12 mol of  $\text{H}_2$

$$\text{hydrogen atoms} = (1.25 \times 10^{21} \text{ C atoms}) \times (12 \text{ mol H}_2) / (6 \text{ mol H}_2 \text{ atoms})$$

$$= 2.50 \times 10^{21} \text{ H}_2 \text{ atoms}$$

b) 1 mol  $\text{C}_6\text{H}_{12}\text{O}_6 = (1.25 \text{ C atoms}) \times (1 \text{ mol C}_6\text{H}_{12}\text{O}_6) / (6 \text{ mol C}) = 0.21 \times 10^{21}$

c) 1 mol  $\text{C}_6\text{H}_{12}\text{O}_6 = (0.21 \times 10^{21} \text{ atoms}) (1 \text{ mol C}_6\text{H}_{12}\text{O}_6) / (6.03 \times 10^{23}) = 3.5 \text{ mol}$

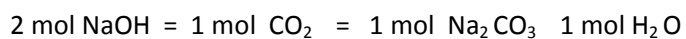
d) mass of glucose =  $3.5 \text{ mol} \times 180 \text{ g/mol} = 6.21$

**3.7**

Sodium hydroxide reacts with CO<sub>2</sub> as follows  $2\text{NaOH}_{(s)} + \text{CO}_{2(g)} \rightarrow \text{Na}_2\text{CO}_{3(s)} + \text{H}_2\text{O}_{(l)}$

Which reagent is the limiting when 1.85 mole NaOH and 1.00 mole CO<sub>2</sub> are allowed to react? How many moles of Na<sub>2</sub>CO<sub>3</sub> can be produced? How many moles of the excess reactant remain after the completion of the reaction?

Answer:



$$\text{Mole of CO}_2 = (1.85 \text{ mol NaOH}) \times (1 \text{ mol CO}_2) / (2 \text{ mol NaOH}) = 0.925 \text{ mol CO}_2$$

The limiting reagent is NaOH

$$1.00 - 0.925 = 0.075 \text{ mole of CO}_2 \text{ (excess reagent)}$$

$$\text{Mole of Na}_2\text{CO}_3 = (1 \text{ mol Na}_2\text{CO}_3) \times (1.85 \text{ mol NaOH}) / (2 \text{ mol NaOH}) = 0.925 \text{ mole}$$