Worksheet - Limiting Reagent Problems #1 - 10

Limiting Reagent Problems #11-20 Limiting reagent tutorial Stoichiometry Menu

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Problem #1: For the combustion of sucrose:

$C_{12}H_{22}O_{11} + 12O_2 \text{ ---> } 12CO_2 + 11H_2O$

there are 10.0 g of sucrose and 10.0 g of oxygen reacting. Which is the limiting reagent?

Solution path #1:

1) Calculate moles of sucrose:

10.0 g / 342.2948 g/mol = 0.0292146 mol

2) Calculate moles of oxygen required to react with moles of sucrose:

From the coefficients, we see that 12 moles of oxygen are require for every one mole of sucrose. Therefore:

0.0292146 mol times 12 = 0.3505752 mole of oxygen required

3) Determine limiting reagent:

Oxygen on hand ⇒ 10.0 g / 31.9988 g/mol = 0.3125 mol

Since the oxygen required is greater than that on hand, it will run out before the sucrose. Oxygen is the limiting reagent.

Solution path #2:

1) Calculate moles:

sucrose ⇒ 0.0292146 mol
oxygen ⇒ 0.3125 mol

2) Divide by coefficients of balanced equation:

sucrose ⇒ 0.0292146 mol / 1 mol = 0.0292146
oxygen ⇒ 0.3125 mol / 12 mol = 0.02604

Oxygen is the lower value. It is the limiting reagent.

The second method above will be the preferred method to determine the limiting reagent in the following problems.

Problem #2: Calculate the number of NaBr formula units formed when 50 NBr_3 molecules and 57 NaOH formula units react?

$2NBr_3 + 3NaOH \text{ ---> } N_2 + 3NaBr + 3HOBr$

Solution:

Comment: we can treat numbers of molecules or formula units in the exact same manner as we would use moles. Keep in mind that the meaning of one mole is that 6.022×10^{23} of that entity (be it molecules or formula units) is present.

1) Determine limiting reagent:

$NBr_3 \Rightarrow 50 \text{ "moles"} / 2 = 25$
$NaOH \Rightarrow 57 \text{ "moles"} / 3 = 19$

NaOH is the lmiting reagent.

Note that there need be no conversion from grams to moles. Discussions of numbers of molecules uses numbers that are directly proportional to the number of moles and do not need to be converted.

2) Use NaOH : NaBr molar ratio:

3 is to 3 as 57 is to x

x = 57 "moles"

Correctly phrased, the answer is 57 formula units.

Comment: when I was in the classroom, teaching the technique for determining the limiting reagent, I would warn against using the results of the division, in this case the 19 for the NaOH, in the next step of the calculation. The 19 is good only for determining the limiting reagent. You need to use the 57 in the next step.

Well, what did I do? You know it's coming . . . .

Yep, I used the 19 when I should have used the 57. It stayed that way for several years, undetected until August 2013, when a student caught it. Thanks, T.

Problem #3: Aluminum reacts with chlorine gas to form aluminum chloride via the following reaction:

$2Al + 3Cl_2 \text{ ---> } 2AlCl_3$

How many grams of aluminum chloride could be produced from 34.0 g of aluminum and 39.0 g of chlorine gas?

Solution:

1) Determine the limiting reagent:

Al ⇒ 34.0 g / 26.98 g/mol = 1.2602 mol
Cl_2 ⇒ 39.0 g / 70.906 g/mol = 0.5500 mol

Al ⇒ 1.2602 mol / 2 =
Cl_2 ⇒ 0.5500 mol / 3 =

Seems pretty obvious that chlorine gas is the limiting reagent. In a situation like this, you don't have to finish the problem unless it's on a test and the teachers wants it finished!

2) Use Cl_2 : $AlCl_3$ molar ratio:

3 is to 2 as 0.5500 mol is to x

x = 0.3667 mol of $AlCl_3$ produced

3) Convert to grams:

0.3667 mol times 133.341 g/mol = 48.9 g (to three sig fig)

Why don't you determine the mass of aluminum that remains after the reaction ceases by using the proper molar ratio?

By the way, you could have done it this way:

48.9 g minus 39.0 g = 9.9 g of Al reacted

34.0 g minus 9.9 g = 24.1 g

It only works this second way if you have mass data on every substance in the reaction. Look back at the first problem in this file and you'll see you can't do it using this second way because you don't know anything about the mass of carbon dioxide produced. In that problem, you have to use the molar ratio way.

Problem #4: Interpret reactions in terms of representative particles, then write balanced chemical equations and compare with your results. Determine limiting and excess reagent and the amount of unreacted excess reactant.

a) 3 atoms of carbon combine with 4 molecules of hydrogen to produce methane (CH_4)
b) 7 molecules of hydrogen and 2 molecules of nitrogen gases react to produce ammonia
c) 4 molecules of hydrogen and 5 molecules of chlorine react.

Solution to a:

1) The balanced equation:

$C + 2H_2$ ---> CH_4

2) Write the carbon-hydrogen molar ratio:

1 : 2

Remember that this ratio can also be understood in terms of atoms and molecules. Thusly:

one atoms of carbon reacts with two molecules of hydrogen

3) Determine limiting reagent:

carbon ⇒ 3/1 = 3
hydrogen ⇒ 4/2 = 2

Hydrogen is the limiting reagent.

4) Determine amount of carbon consumed:

1 is to 2 as x is to 4

x = 2

5) Determine remaining amount of carbon, the excess reagent:

3 minus 2 = 1 atom of carbon remaining

Answers to b: $N_2 + 3H_2 \text{ ---> } 2NH_3$

The molar ratio of importance is nitrogen to hydrogen. It is 1 : 3.

Nitrogen is the limiting reagent.

One molecule of hydrogen remains.

Answers to c:

$H_2 + Cl_2 \text{ ---> } 2HCl$

1 : 1. Chlorine in excess by one molecule.

Problem #5: Suppose 316.0 g aluminum sulfide reacts with 493.0 g of water. What mass of the excess reactant remains?

The unbalanced equation is:

$Al_2S_3 + H_2O \text{ ---> } Al(OH)_3 + H_2S$

Solution:

1) Balance the equation:

$Al_2S_3 + 6H_2O \text{ ---> } 2Al(OH)_3 + 3H_2S$

2) Determine moles, then limiting reagent:

Al_2S_3 ⇒ 316.0 g / 150.159 g/mol = 2.104436 mol
H_2O ⇒ 493.0 g / 18.015 g/mol = 27.366 mol

Al_2S_3 ⇒ 2.104436 / 1 = 2.104436
H_2O ⇒ 27.366 / 6 = 4.561

Al_2S_3 is the limiting reagent.

3) Determine grams of water that react:

The molar ratio to use is 1:6

1 is to 6 as 2.104436 mol is to x

x = 12.626616 mol of water used

12.626616 mol times 18.105 g/mol = 227.4685 g

4) Determine excess:

493.0 g minus 227.46848724 = 265.5 g (to 4 sig figs)

Notice how the question only asks about the excess reagent, but you have to go through the entire set of steps (determine moles, determine limiting reagent, use molar ratio) to get to the answer. Tricky!

Problem #6: In this reaction:

$CaCO_3 + 2HCl \text{ ---> } CaCl_2 + CO_2 + H_2O$

6.088 g $CaCO_3$ reacted with 2.852 g HCl. What mass of $CaCO_3$ remains unreacted?

Solution:

1) Let's verify that the HCl is limiting:

$CaCO_3$ ⇒ 6.088 g / 100.086 g/mol = 0.0608277 mol
HCl ⇒ 2.852 g / 36.461 g/mol = 0.0782206 mol

By inspection, we see that HCl is the limiting reagent. (Mentally divide both values by their respective coefficient from the equation to see this.)

Wouldn't that have been cute if you just assumed the HCl was limiting and the question writer made it a bit of a trick question by making the calcium carbonate limiting?

2) Determine moles, then grams of calcium carbonate used:

1 is to 2 as x is to 0.0782206 mol

x = 0.0391103 mol

0.0391103 mol times 100.086 g/mol = 3.914 g

3) Determine grams of $CaCO_3$ remaining:

6.088 g minus 3.914 g = 2.174 g

Problem #7: How many grams of PF_5 can be formed from 9.46 g of PF_3 and 9.42 g of XeF_4 in the following reaction?

$2PF_3 + XeF_4 \text{ ---> } 2PF_5 + Xe$

Solution:

1) Determine moles:

$PF_3 \Rightarrow$ 9.46 g / 87.968 g/mol = 0.10754 mol
$XeF_4 \Rightarrow$ 9.42 g / 207.282 g/mol = 0.045445 mol

2) Determine limiting reagent:

$PF_3 \Rightarrow$ 0.10754 / 2 = 0.05377
$XeF_4 \Rightarrow$ 0.045445 / 1 = 0.045445

XeF_4 is limiting

2) Use XeF_4 : PF_5 molar ratio:

1 is to 2 as 0.045445 mol is to x

x = 0.090890 mol of PF_5 produced

3) Determine grams of PF_5:

0.090890 mol times 125.964 g/mol = 11.45 g

Problem #8: How many grams of IF_5 would be produced using 44.01 grams of I_2O_5 and 101.0 grams of BrF_3?

$6I_2O_5 + 20BrF_3 \text{ ---> } 12IF_5 + 15O_2 + 10Br_2$

Solution:

1) Determine moles:

$I_2O_5 \Rightarrow$ 44.01 g / 333.795 g/mol = 0.1318474 mol
$BrF_3 \Rightarrow$ 101.0 g / 136.898 g/mol = 0.7377756 mol

2) Determine limiting reagent:

I_2O_5 ⇒ 0.1318474 / 6 = 0.02197457
BrF_3 ⇒ 0.7377756 / 20 = 0.03688878

I_2O_5 is limiting.

2) Use I_2O_5 : IF_5 molar ratio:

The ratio is 6 to 12, so I'll use 1 to 2

1 is to 2 as 0.1318474 mol is to x

x = 0.2636948 mol of IF_5 produced

3) Convert moles to grams:

0.2636948 mol times 221.89 g/mol = 58.51 g (to 4 sig figs)

Problem #9: 950.0 grams of copper(II) sulfate are reacted with 460.0 grams of zinc metal. (a) What is the theoretical yield of Cu? (b) If 295.8 grams of copper are actually obtained from this reaction, what is the percent yield?

Solution to a:

1) The balanced chemical equation is:

$CuSO_4$ + Zn ---> $ZnSO_4$ + Cu

2) Determine limiting reagent:

$CuSO_4$ ⇒ 950.0 g / 159.607 g/mol = 5.95212 mol
Zn ⇒ 460.0 g / 65.38 g/mol = 7.03579 mol

$CuSO_4$ is limiting.

The coefficients of Zn and $CuSO_4$ are both one, so I just eliminted the whole 'divide by 1' thing.

3) Determine moles, then grams of Cu:

5.95212 mol of Cu is produced (due to the 1 : 1 molar ratio involved)

5.95212 mol times 63.546 g/mol = 378.2 g

Solution to b:

Percent yield is:

295.8 g / 378.2 g = 78.21 %

Problem #10: What weight of each substance is present after 0.4500 g of P_4O_{10} and 1.5000 g of PCl_5 are reacted completely?

$P_4O_{10} + 6PCl_5 \text{ ---> } 10POCl_3$

Solution:

1) Determine moles:

$P_4O_{10} \Rightarrow 0.4500 \text{ g} / 283.886 \text{ g/mol} = 0.00158514 \text{ mol}$
$PCl_5 \Rightarrow 1.5000 / 208.239 \text{ g/mol} = 0.00720326 \text{ mol}$

2) Determine limiting reagent:

$P_4O_{10} \Rightarrow 0.00158514 / 1 = 0.00158514$
$PCl_5 \Rightarrow 0.00720326 / 6 = 0.00120054$

PCl_5 is limiting.

2) Determine mass of P_4O_{10} remaining:

Use 1 : 6 molar ratio.

1 is to 6 as x is to 0.00720326 mol

x = 0.00120054 mol of P_4O_{10} remaining

0.00158514 mol minus 0.00120054 mol = 0.0003846 mol

0.0003846 mol times 283.886 g/mol = 0.1092 g

3) Determine mass of $POCl_3$ produced:

Use 6 : 10 molar ratio (or, if you prefer, use 3 : 5).

3 is to 5 as 0.00720326 mol is to x

x = 0.01200543 mol of $POCl_3$ produced

0.01200543 mol times 153.332 g/mol = 1.8408 g

Since PCl_5 is limiting, zero grams of it will remain.

Limiting Reagent Problems #11-20 Limiting reagent tutorial Stoichiometry Menu