SET 1 COUNTING MOLES
(limiting reagents)

Q1. Interpret the following equation in terms of interacting numbers of moles.

$$4NH_{3(g)} + 6NO_{(g)} \longrightarrow 5N_{2(g)} + 6H_2O_{(g)}$$

When 1.2 moles of NH_3 reacts with 3.5 moles of NO.

A. Which reagent is the limiting reagent?
B. Which reagent is in excess and by how many moles?
C. How many moles of N_2 are formed?
D. How many moles of H_2O are formed?

Q2. When 0.2 moles of K reacts with 2.35 moles of O_2.

$$4K_{(s)} + O_{2(g)} \longrightarrow 2K_2O_{(s)}$$

A. Which reagent is the limiting reagent?
B. Which reagent is in excess and by how many moles?
C. How many moles of K_2O are formed?

Q3. For each of these balanced equations, identify the limiting reagent for the given combination of reactants.

a. $2Al + 3Cl_2 \longrightarrow 2AlCl_3$
3.6 mol, 5.3 mol

b. $2H_2 + O_2 \longrightarrow 2H_2O$
6.4 mol, 3.4 mol

c. $P_4O_{10} + 6H_2O \longrightarrow 4H_3PO_4$
0.48 mol, 1.52 mol

d. $4P + 5O_2 \longrightarrow P_4O_{10}$
14.5 mol, 18.0 mol

Q4. For each of the four reactions in Q4, calculate the number of moles of product formed.

Q5. For each of the four reactions in Q4, calculate the number of moles of excess reagent remaining after the reaction has used up the limiting reagent.

Q6. What is the limiting reagent when 0.25 mol of P_4 and 0.25 mol of O_2 react

$$P_4 + 5O_2 \longrightarrow P_4O_{10}$$

Q7. What is the limiting reagent when 0.25 mol of Cr and 0.50 mol of H_3PO_4 react according to the following reaction?

$$2Cr + H_3PO_4 \longrightarrow 2CrPO_4 + 3H_2$$

EXAMPLE 2

Sulfuric acid forms (H_2SO_4) forms in the chemical reaction

$$2SO_2 + O_2 + 2H_2O \longrightarrow 2H_2SO_4$$

Suppose 6.24 mol SO_2, 5.47 mol O_2, and 6.94 mol H_2O are mixed together and the reaction proceeds until one of the reactants is used up.

A. Which is the limiting reagent?
B. What number of moles of H_2SO_4 is produced?
C. What number of moles of the other reactants remain?

Solution

If all the SO_2 reacted, it would give

$$6.24 \text{ mol } SO_2 \times \frac{2 \text{ mol } H_2SO_4}{2 \text{ mol } SO_2} = 6.24 \text{ mol } H_2SO_4$$

If all the O_2 reacted, it would give

$$5.47 \text{ mol } O_2 \times \frac{2 \text{ mol } H_2SO_4}{1 \text{ mol } O_2} = 10.94 \text{ mol } H_2SO_4$$

If all the H_2O reacted, it would give

$$6.94 \text{ mol } H_2O \times \frac{2 \text{ mol } H_2SO_4}{2 \text{ mol } H_2O} = 6.94 \text{ mol } H_2SO_4$$

In this case the SO_2 is the limiting reagent, because the computation based on its amount gives the smallest amount of product (6.24 mol H_2SO_4). Oxygen and water are present in excess. After the reaction the amount of each that remains is the original amount minus the amount reacting:

$$\text{Moles } O_2 = 5.47 \text{ mol } O_2 - (6.24 \text{ mol } SO_2 \times \frac{1 \text{ mol } O_2}{2 \text{ mol } SO_2})$$

$$= 5.47 - 3.12 \text{ mol } O_2 = 2.35 \text{ mol } O_2$$

$$\text{Moles } H_2O = 6.94 \text{ mol } H_2O - (6.24 \text{ mol } SO_2 \times \frac{2 \text{ mol } H_2O}{2 \text{ mol } SO_2})$$

$$= 6.94 - 6.24 \text{ mol } H_2O = 0.7 \text{ mol } H_2O$$

A. Which is the limiting reagent? **Ans:** SO_2
B. What number of moles of H_2SO_4 is produced? **Ans:** 6.24 mol H_2SO_4
C. What number of moles of the other reactants remain? **Ans:** 2.35 mol O_2 **&** 0.7 mol H_2O

Q8. Consider the reaction

$$4Al_{(s)} + 3O_{2(g)} \longrightarrow 2Al_2O_{3(s)}$$

Identify the limiting reagent in each of the following reaction mixtures:

a. 1.0 mol *Al* and 1.0 mol O_2
b. 2.0 mol *Al* and 4.0 mol O_2
c. 0.50 mol *Al* and 0.75 mol O_2

Q9. Potassium superoxide, KO_2, is used in rebreathing gas masks to generate oxygen.

$$4KO_{2(s)} + 2H_2O_{(l)} \longrightarrow 4KOH_{(s)} + 3O_{2(g)}$$

If a reaction vessel contains 0.25 mol KO_2 and 0.15 mol H_2O, what is the limiting reagent (reactant)? How many moles of oxygen can be produced?

Q10. Large quantities of ammonia are burned in the presence of a platinum catalyst to give nitric oxide, as the first step in the preparation of nitric acid.

$$4NH_{3(g)} + 5O_{2(g)} \longrightarrow 4NO_{(g)} + 2H_2O_{(g)}$$

Suppose a vessel contains 0.120 mol NH_3 and 0.140 mol O_2. What is the limiting reagent (reactant)? How many moles of NO could be obtained?

Q11. Lead(II) nitrate and magnesium sulfate solutions react together to form a precipitate of lead(II) sulfate according to the equation:

$$Pb(NO_3)_{2(aq)} + MgSO_{4(aq)} \longrightarrow PbSO_{4(s)} + Mg(NO_3)_{2(aq)}$$

Which reactant would be in excess, and by what amount (mol), if solutions containing the following quantities of lead(II) nitrate and magnesium sulfate were added to each other?

A. 1.0 mol of lead(II) nitrate and 2.0 mol of magnesium sulfate
B. 0.50 mol of lead(II) nitrate and 2.0 mol of magnesium sulfate
C. 3.0 mol of lead(II) nitrate and 0.20 mol of magnesium sulfate

Q12. Zinc metal reacts with hydrochloric acid by the following reaction:

$$Zn_{(s)} + 2HCl_{(aq)} \longrightarrow ZnCl_{2(aq)} + H_{2(g)}$$

If 0.30 mol Zn is added to hydrochloric acid containing 0.52 mol HC*l*, how many moles of H_2 are produced?

Q13. Aluminium chloride, $AlCl_3$, is used as a catalyst in various industrial reactions. It is prepared from hydrogen chloride gas and aluminium metal shavings.

$$2Al_{(s)} + 6HCl_{(aq)} \longrightarrow 2AlCl_{3(aq)} + 3H_{2(g)}$$

How many moles of $AlCl_3$ can be prepared from a mixture of 0.15 mol *Al* and 0.35 mol HC*l*?

Answers: SET 1 Counting Moles (limiting reagents)

1. A. Select one of the products e.g. N_2. Take each reactant in turn and work out how much N_2 it would produce if it was fully consumed (all reacted).

$n(N_2) = 5/4 \times n(NH_3) = 5/4 \times 1.2 = 1.5$ moles of N_2
$n(N_2) = 5/6 \times n(NO) = 5/6 \times 3.5 = 2.92$ moles of N_2

Since NH_3 produces the least amount of N_2 ($1.5 < 2.92$), $\therefore$ NH_3 is the limiting reagent. NH_3 as limiting reagent limits the amount of all products formed and the amount of the XS reactant that is consumed.

B. $n(NO)$ reacting $= 6/4 \times n(NH_3) = 6/4 \times 1.2 = 1.8$
$n(NO)$ in XS $= n(NO)$ initially $- n(NO)$ reacting $= 3.5 - 1.8 = 1.7$ moles.

C. $n(N_2) = 5/4 \times n(NH_3) = 5/4 \times 1.2 = 1.5$ moles of N_2

D. $n(H_2O) = 6/4 \times n(NH_3) = 6/4 \times 1.2 = 1.8$ moles of H_2O

2. A. Take each reactant in turn and work out how much K_2O it would produce if it was fully consumed (all reacted).

$n(K_2O) = 2/4 \times n(K) = 2/4 \times 0.2 = 0.1$ moles of K_2O
$n(K_2O) = 2 \times n(O_2) = 2 \times 2.35 = 4.7$ moles of K_2O

Since K produces the least amount of K_2O ($0.1 < 4.7$), $\therefore$ K is the limiting reagent. K as limiting reagent limits the amount of all products formed and the amount of the XS reactant that is consumed.

B. $n(O_2)$ reacting $= ¼ \times n(K) = ¼ \times 0.2 = 0.05$ moles O_2
$n(O_2)$ in XS $= n(O_2)$ initially $- n(O_2)$ reacting $= 2.35 - 0.05 = 2.3$ moles.

C. $n(K_2O) = 2/4 \times n(K) = 2/4 \times 0.2 = 0.1$ moles of K_2O

3, 4 & 5.

	Limiting Reagent	Product	XS
a.	Cl_2	3.53	0.0667
b.	H_2	6.4	0.2
c.	H_2O	1.01	0.227
d.	O_2	3.6	0.1

6. O_2
7. Cr
8. a. Al b. Al c. Al
9. KO_2 is limiting; 0.19 moles of O_2
10. O_2 is limiting; 0.112 moles of NO
11. A. $MgSO_4$, 1.0 mol
    B. $MgSO_4$, 1.5 mol
    C. $Pb(NO_3)_2$, 2.8 mol
12. 0.26 mol.
13. HCl is limiting; 0.117 moles of $AlCl_3$

SET 2 COUNTING MOLES
(limiting reagents)

Q1. Acetylene, C_2H_2, will burn in the presence of oxygen.

$$2C_2H_{2(g)} + 5O_{2(g)} \longrightarrow 4CO_{2(g)} + 2H_2O_{(g)}$$

How many grams of water can be produced by the reaction of 2.40 mol of C_2H_2 with 7.4 mol of O_2?

Q2. What is the limiting reagent when 1.00 g of Si and 1.00 g of N combine according to the following reaction?

$$3Si + 2N_2 \longrightarrow Si_3N_4$$

Q3. What is the limiting reagent when 10.0 g of propane, C_3H_8, is burned with 25 g of oxygen?

$$C_3H_{8(g)} + 5O_{2(g)} \longrightarrow 3CO_{2(g)} + 4H_2O_{(g)}$$

Q4. What mass of H_2 is formed when 2.430 g of Mg reacts with a solution containing 9.125 g of HC*l*?

$$Mg_{(s)} + 2HCl_{(aq)} \longrightarrow MgCl_{2(aq)} + H_{2(g)}$$

Q5. A. What mass of P_2I_4 is produced by reacting 2.00 g of P_4O_6 with 2.00 g of I_2 according to

$$5P_4O_{6(s)} + 8I_{2(s)} \longrightarrow 4P_2I_{4(s)} + 3P_4O_{10(s)}$$

B. Which reactant is in excess and by how many grams?
C. What mass of P_4O_{10} forms?

Q6. When a mixture of silver metal and sulphur is heated, silver sulphide is formed:

$$16Ag_{(s)} + S_{8(s)} \longrightarrow 8Ag_2S_{(s)}$$

A. What mass of Ag_2S is produced from a mixture of 2.0 g Ag and 2.0 g S_8?
B. What mass of which reactant is left unreacted?

Q7. Mercury and bromine will react with each other to produce mercury(II) bromide:

$$Hg_{(l)} + Br_{2(l)} \longrightarrow HgBr_{2(s)}$$

A. What mass of $HgBr_2$ can be produced from the reaction of 10.0 g Hg and 9.00 g Br_2?
B. What mass of which reagent is left unreacted?

Answers: SET 2 Counting Moles (limiting reagents)

1. 43.2 g
2. Si
3. O_2
4. 0.200 g
5. A. 2.24 g
   B. P_4O_6 by 0.917 g
   C. 0.839 g
6. A. 2.4 g B. 1.7 g S_8 unreacted.
7. A.

$n(Hg) = \frac{10}{200.6} = 0.0498$ mol $\quad n(Br_2) = \frac{9}{159.8} = 0.0563$ mol

limiting reagent Hg

$n(HgBr_2)$ $0.0498 = \frac{m}{360.4}$ $\quad m = 17.9g$.

B. Br_2 $0.0563 - 0.0498 = 0.0065$ mols

$n(Br_2)_{unreacted} =$

$0.0065 = \frac{m}{159.8}$

$m = 1.04g$

6) Ag $\frac{2}{107.9} = 0.0185$ mols $\quad$ S $\frac{2}{256} = 0.00781$ mols

$n(Ag)\ \frac{1}{16} = n(S) = 0.001156$ mols

∴ Ag limiting reagent

a) $n(Ag) \times \frac{8}{16} = n(Ag_2S)$

$0.0185 \times 1/2 = n(Ag_2S) = 0.00925$ mols

$\underline{2.3g} = \frac{m}{246}$

b) Excess n(S) − n(S) used

0.00781 − 0.001156

n(S) excess = 0.006654 mols

$= \frac{m}{256} = 1.70g.$

5) a)

P_4O_6

$\frac{2}{219.88} = 0.00909$ mols

I_2

$\frac{2}{253.8} = 0.00788$ mols

$n(P_4O_6) \frac{8}{5} = n(I_2) = 0.014544$

∴ I_2 limiting reagent.

b) So $n(I_2) = 0.00788 \times \frac{5}{8} = 0.004925$ mols

Excess $n(P_4O_6)$ − $n(I_2)$ used

0.00909 − 0.004925

= 0.004165 mols

$\frac{m}{Mr} = \frac{m}{219.88} = 0.916g.$