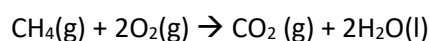


Worksheet on excess and limiting reactants/reagents.

When dealing with questions where the mol of more than one reactant is known, students must determine which reactant is in excess. There are two possibilities, the reactants are in the right stoichiometric ratio or that one of them is in excess. If the latter is the case then the limiting reagent/reactant is the one used to perform stoichiometric calculations.

Eg Methane undergoes complete combustion, at SLC, in atmospheric oxygen to produce carbon dioxide and water. The balanced chemical equation is given below.



If 97.6 litres of methane was mixed with 150 litres of oxygen gas and ignited what mass, in grams, of  $\text{CO}_2$  is formed at the completion of the combustion reaction.

Step 1 find the limiting reactant.

Reactant	mol	Limiting quotient Mol/coefficient
$\text{CH}_4$	$97.6 / 24.8 = 3.94$	$3.94/1 = 3.94$
$\text{O}_2$	$150/24.8 = 6.05$	$6.05/2 = 3.02$

=> Identify the reactant with the lowest limiting quotient as being the limiting reactant, in this case it is  $\text{O}_2$ .

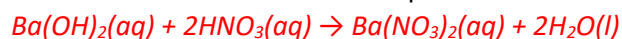
Step 2 Using the limiting reactant find the mol of  $\text{CO}_2$  produced.

$$\Rightarrow 6.05 \times \frac{1}{2} = 3.03 \text{ mol}$$

Step 3 Find the mass of  $\text{CO}_2$

$$\Rightarrow 3.03 \times 44.0 = 133 \text{ grams}$$

- 50.00 mL of a 0.200 M barium hydroxide solution is mixed with 50.00 mL of a 0.300 M nitric acid solution and allowed to react
  - Give the overall balanced chemical equation for the reaction, states included.



- b. Identify the excess reactant and calculate the amount, in grams, by which it is in excess. Show all working out and give the answer to the right number of significant figures.

Reactant	mol	Limiting quotient Mol/coefficient
Ba(OH) <sub>2</sub>	$0.05000 \times 0.200 = 0.0100$	$0.0100/1 = 0.0100$
HNO <sub>3</sub>	$0.05000 \times 0.300 = 0.0150$	$0.0150/2 = 0.00750$

*Step 1 calculate the mol of each reactant.*

*mol of Ba(OH)<sub>2</sub> =  $0.05000 \times 0.200 = 0.0100$*

*Mol of HNO<sub>3</sub> =  $0.05000 \times 0.300 = 0.0150$*

*Step 2 To identify the excess reactant divide the mol of each reactant by its coefficient in the balanced chemical equation given in part a. above to determine its limiting quotient. Take the reactant with the highest limiting quotient as the one in excess.*

*Ba(OH)<sub>2</sub> (limiting quotient) =  $0.0100/1 = 0.0100$*

*HNO<sub>3</sub> (limiting quotient) =  $0.0150 / 2 = 0.00750$*

*Ba(OH)<sub>2</sub> is the reactant in excess.*

*How much is it in excess by?*

*Step 1 using the limiting reactant calculate how much, in mol, of the excess is used up.*

*Mol of Ba(OH)<sub>2</sub> used up =  $0.0150 \times \frac{1}{2} = 0.0075$  mol is used up.*

*Step 2 Find the mol of Ba(OH)<sub>2</sub> remaining*

*=>  $0.0100 - 0.0075 = 0.0025$*

*Step 3 mass of Ba(OH)<sub>2</sub> in excess =  $0.0025 \times 171.34 = 0.428g$*

2. Methane is reacted with oxygen gas at SLC to provide heat to increase the temperature of 5.00 kilograms of pure water.
- a. Give the balanced chemical equation for the combustion of methane gas. Include states  
 $CH_4(g) + 2O_2 \rightarrow CO_2(g) + 2H_2O(l)$
- b. A mixture of 20.50 litres of methane and 40.0 litres of oxygen gas was ignited.
- i. Calculate the total volume of gas produced if the temperature and pressure remained at SLC.

Reactant	mol	Limiting quotient Mol/coefficient
Ba(OH) <sub>2</sub>	$20.5 / 24.8 = 0.827$	$0.827/1 = 0.827$
HNO <sub>3</sub>	$40.0 \times 24.8 = 1.613$	$1.613 / 2 = 0.807$

*Step 1 calculate the mol of each reactant.*

*mol of CH<sub>4</sub> =  $20.5 / 24.8 = 0.827$*

*Mol of O<sub>2</sub> =  $40.0 \times 24.8 = 1.613$*

*Step 2 Identify the limiting reactant*

*CH<sub>4</sub> (limiting quotient) =  $0.827/1 = 0.827$*

*O<sub>2</sub> (limiting quotient) =  $1.613 / 2 = 0.807$*

*O<sub>2</sub> is the limiting reactant.*

*Using the limiting reactant (O<sub>2</sub>) calculate the amount of CO<sub>2</sub> produced. At SLC, water is a liquid.*

*Step 1 mol of CO<sub>2</sub> produced =  $0.807 \times \frac{1}{2} = 0.4035$  mol*

*Step 2 find the volume at SLC =  $0.4035 \times 24.8 = 10.0$  L*

- ii. What is the total volume, in litres, of gas remaining after the reaction is complete at SLC.

*Step 1 – the total volume of gas is made up of the excess gas and product gas. Since the volume of product gas has already been calculated in b i. above the excess gas needs to be calculated.*

$$\Rightarrow \text{mol of CH}_4 \text{ reacted} = 0.807 \times \frac{1}{2} = 0.4035$$

$$\Rightarrow \text{mol of CH}_4 \text{ remaining} = 0.827 - 0.4035 = 0.424$$

$$\Rightarrow \text{volume of CH}_4 \text{ remaining} = 0.424 \times 24.8 = 10.5$$

Step 2 – total volume of gas is therefore

$$10.0 + 10.5 = 20.5 \text{ L}$$

- c. Calculate the final temperature of the 5.00 kg of water assuming that all the energy produced during the combustion reaction was absorbed by the water?

*Step 1 – from previous calculations, of the mol of CH<sub>4</sub> that reacted, obtain the total energy given out by the combustion reaction.*

*From the data book the molar heat of combustion of methane is given as 890 kJ mol<sup>-1</sup>*

$$\Rightarrow 0.4035 \times 890 = 359.1 \text{ kJ}$$

*Step 2 – Find the change in temperature.*

$$\Rightarrow \Delta T = 359100 / (4.18 \times 5000) = 17.2 \text{ }^\circ\text{C}$$

*Step 3 final temp*

$$\Rightarrow 25.0 + 17.2 = 42.2 \text{ }^\circ\text{C}.$$

3. An amount of 2.50 grams of calcium carbonate (CaCO<sub>3</sub>) pellets was placed in a beaker containing 500 mL of a 0.100 M HCl solution.

- a. Give the balanced chemical equation for the reaction between CaCl<sub>2</sub> and HCl, states included, where products are either in aqueous, liquid or gaseous states.



- b. This reaction was conducted at SLC. Find the mass, in grams, of gaseous product that is formed?

Reactant	mol	Limiting quotient Mol/coefficient
CaCO <sub>3</sub>	$2.50 / 100 = 0.0250$	$0.0250/1 = 0.0250$
HCl	$0.500 \times 0.100 = 0.0500$	$0.0500 / 2 = 0.0250$

*Step 1 calculate the mol of each reactant.*

$$\text{mol of CaCO}_3 = 2.50 / 100 = 0.0250$$

$$\text{Mol of HCl} = C \times V = 0.100 \times 0.500 = 0.0500$$

*Step 2 To identify the excess reactant divide the mol of each reactant by its coefficient in the balanced chemical equation given in part a. above to determine its limiting quotient. Take the reactant with the highest limiting quotient as the one in excess.*

$$\text{CaCO}_3 \text{ (limiting quotient t)} = 0.0250/1 = 0.0250$$

$$\text{HCl (limiting quotient)} = 0.0500 / 2 = 0.0250$$

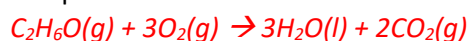
*Both reactants have the same limiting quotient so they are in the exact stoichiometric ratio. We can use any one of the two reactants to perform stoichiometric calculations.*

=> Find the mol of CO<sub>2</sub> formed  
 => If 0.0500 mol of HCl reacts then 0.0250 mols of CO<sub>2</sub> is formed.  
 => mass of CO<sub>2</sub> = 0.0250 X 44.0 = 1.10 g

4. Vapourised bioethanol is used as a fuel to propel a new hybrid-vehicle. The engine consumes 3.00 litres of gaseous ethanol and mixes it with 50.0 litres of air, which is composed of 20.0% oxygen gas. The mixture is ignited at SLC.



- a. Write a balanced chemical equation for the complete combustion of ethanol at SLC. States included.



- b. Identify the reactant in excess, show all working out.

Reactant	mol	Limiting quotient Mol/coefficient
C <sub>2</sub> H <sub>6</sub> O	$3.00 / 24.8 = 0.121$	$0.121 / 1 = 0.121$
O <sub>2</sub>	$50.0 \times (20/100) / 24.8 = 0.403$	$0.403 / 3 = 0.134$

- c.

Step 1 calculate the mol of each reactant.

$$\text{mol of C}_2\text{H}_6\text{O} = 3.00 / 24.8 = 0.121$$

$$\text{Mol of O}_2 = 50.0 \times (20/100) / 24.8 = 0.403$$

Step 2 To identify the excess reactant divide the mol of each reactant by its coefficient in the balanced chemical equation given in part a. above to determine its limiting quotient.

Take the reactant with the highest limiting quotient as the one in excess.

$$\text{C}_2\text{H}_6\text{O} (\text{limiting quotient}) = 0.121 / 1 = 0.121$$

$$\text{O}_2 (\text{limiting quotient}) = 0.403 / 3 = 0.134$$

Oxygen is in excess so ethanol is the limiting reactant and should be used for all calculations .

- d. Calculate the amount of heat energy, in kJ, produced during the complete combustion of 3.00 litres of gaseous bioethanol with 50.0 litres of air at SLC.

Using the limiting reactant and data-booklet calculate the heat energy released.

$$\Rightarrow \text{mol of C}_2\text{H}_6\text{O} \text{ that reacted fully} = 0.121, \text{ molar heat of combustion} = 1360 \text{ kJ mol}^{-1}$$

$$\Rightarrow \text{Energy (kJ)} = 0.121 \times 1360 = 165\text{kJ}$$

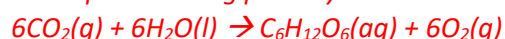
- e. Bioethanol is relatively expensive to produce and transport.

- i. Suggest a way that car manufacturers can guarantee that the amount of ethanol pumped into the engine is totally burnt to release the maximum possible heat energy.

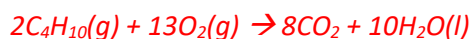
Always mix the fuel with excess oxygen to ensure that ethanol is completely burnt in the engine and not expelled as unburnt fuel. Air is relatively cheap so using excess air will not increase the cost of operating the vehicle.

- ii. Give one advantage of using bioethanol as a fuel. Provide at least one chemical reaction to support your answer.

It can be replaced in a reasonably short period of time so that it does not run out. It is renewable. It adds less CO<sub>2</sub> to the atmosphere than fossil fuels due to the fact that the CO<sub>2</sub> produced during combustion was originally absorbed from the atmosphere during photosynthesis.



5. Butane gas undergoes complete combustion when mixed with oxygen.
- a. Write the balanced chemical equation for the complete combustion of butane gas in the presence of atmospheric oxygen at SLC. States included.



- b. A mixture made up of 20.0 litres of butane gas and 100 litres of pure oxygen gas is ignited.
- i. Calculate the total volume, in litres, of product gas.

Reactant	mol	Limiting quotient Mol/coefficient
$C_4H_{10}$	$20.00 / 24.8 = 0.806$	$0.806 / 2 = 0.403$
$O_2$	$100.0 / 24.8 = 4.03$	$4.03 / 13 = 0.310$

*Step 1 calculate the mol of each reactant.*

$$\text{mol of } C_4H_{10} = 20.00 / 24.8 = 0.806$$

$$\text{Mol of } O_2 = 100.0 / 24.8 = 4.03$$

*Step 2 To identify the excess reactant divide the mol of each reactant by its coefficient in the balanced chemical equation given in part a. above to determine its limiting quotient. Take the reactant with the highest limiting quotient as the one in excess.*

$$C_4H_{10} (\text{limiting quotient}) = 0.806 / 2 = 0.403$$

$$O_2 (\text{limiting quotient}) = 4.03 / 13 = 0.310$$

*butane is in excess so oxygen is the limiting reactant and should be used for all calculations .*

*Step 2 using the mol of oxygen calculate the mol of  $CO_2$  produced. At SLC water is a liquid.*

$$\Rightarrow 4.03 \times (8/13) = 2.48 \text{ mol}$$

$$\text{Step 3 Volume of } CO_2 = 2.48 \times 24.8 = 61.5 \text{ L}$$

- ii. What is the total volume, in litres, of gas left over after the combustion reaction is complete.

*The total volume includes the unreacted gas as well as product gas.*

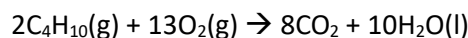
$$\text{mol of butane used} = 4.03 \times 2/13 = 0.62$$

$$\text{mol of butane in excess} = 0.806 - 0.62 = 0.19$$

$$\text{Volume occupied by butane at SLC} = 0.19 \times 24.8 = 4.61 \text{ litres}$$

$$\text{Total volume} = 4.61 + 61.5 = 66.1 \text{ L.}$$

6. In another experiment 5.80 grams of butane was mixed with 16.0 grams of oxygen gas in a sealed 5.00 litre vessel and ignited. The balanced chemical equation for the reaction is shown below.



Calculate the pressure, in kPa, exerted on the walls of the container if the temperature of the gaseous mixture is allowed to reach 70.0 °C.

Reactant	mol	Limiting quotient Mol/coefficient
$\text{C}_4\text{H}_{10}$	$5.80 / 58.0 = 0.100$	$0.100 / 2 = 0.0500$
$\text{O}_2$	$16.0 / 32.0 = 0.500$	$0.500 / 13 = 0.0385$

*Step 1 calculate the mol of each reactant.*

$$\text{mol of } \text{C}_4\text{H}_{10} = 5.80 / 58.0 = 0.100$$

$$\text{Mol of } \text{O}_2 = 16.0 / 32.0 = 0.500$$

*Step 2 To identify the excess reactant divide the mol of each reactant by its coefficient in the balanced chemical equation given in part a. above to determine its limiting quotient. Take the reactant with the highest limiting quotient as the one in excess.*

$$\text{C}_4\text{H}_{10} (\text{limiting quotient}) = 0.100 / 2 = 0.0500$$

$$\text{O}_2 (\text{limiting quotient}) = 0.500 / 13 = 0.0385$$

*butane is in excess so oxygen is the limiting reactant and should be used for all calculations .*

*Step 2 using the mol of oxygen calculate the mol of CO<sub>2</sub> produced. At 70 °C water is a liquid.*

$$\Rightarrow 0.500 \times (8/13) = 0.308 \text{ mol}$$

*Step 3 Calculate the amount, in mol, of butane remaining.*

*\Rightarrow calculate the amount of butane reacting*

$$\Rightarrow 0.5 \times (2/13) = 0.0770$$

*\Rightarrow calculate the amount of butane remaining.*

$$\Rightarrow 0.100 - 0.0770 = 0.0230$$

*Step 4 Calculate the total mol of gas present after ignition.*

$$\Rightarrow 0.0230 + 0.308 = 0.331 \text{ mol}$$

*Step 5 Calculate the pressure in kPa*

$$\Rightarrow PV = nRT$$

$$\Rightarrow P = nRT / V$$

$$\Rightarrow P = 0.331 \times 8.31 \times 343 / 5.00 = 189 \text{ kPa}$$