Reacting mass problems 2

Remember

Check with your teacher whether you should involve moles in your calculations, or whether you may use the quick check method instead. Here is an example of this method.

5.40 g of aluminium reacts completely with oxygen: $4Al + 3O_2 \rightarrow 2Al_2O_3$
Calculate the mass of aluminium oxide formed in the reaction. Relative masses: Al = 27, Al_2O_3 = 102

$$\text{mass of } Al_2O_3 = \text{mass of Al} \times \frac{\text{total relative mass of } Al_2O_3}{\text{total relative mass of Al}} = 5.40 \times \frac{(2 \times 102)}{(4 \times 27)} = 10.2 \text{ g}$$

Questions

1. Sodium reacts with oxygen to form sodium oxide: $4Na + O_2 \rightarrow 2Na_2O$
   Calculate the maximum mass of sodium dioxide that can be formed from 0.46 g of sodium.

2. Ammonia is manufactured using the Haber process: $N_2 + 3H_2 \rightleftharpoons 2NH_3$
   Calculate the mass of ammonia formed if nitrogen reacts completely with 480 g of hydrogen.
   [Note: the double-headed arrow $\rightleftharpoons$ shows that the reaction is reversible. You can ignore it here.]

3. Copper(II) oxide can be reduced by heating with carbon: $2CuO + C \rightarrow 2Cu + CO_2$
   Calculate the mass of carbon needed to react completely with 7.95 g of copper(II) oxide.

4. Iron is manufactured in a huge industrial furnace. One of the reactions that happens in the blast furnace involves iron(III) oxide and carbon monoxide:

$$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$$

   (a) Calculate the mass of iron(III) oxide needed to produce 112 g of iron in this reaction.

   (b) Use your answer to part (a) to calculate the mass of iron that can be made from 320 tonnes of iron(III) oxide.

   (c) You can calculate the percentage purity of a substance using this equation:

$$\%\text{ purity} = \frac{\text{actual mass of substance obtained}}{\text{expected mass of substance obtained}} \times 100$$

   Iron ore is impure iron(III) oxide. A blast furnace produces 168 tonnes of iron from 320 tonnes of an iron ore. Use your answer to part (b) to calculate the percentage purity of this iron ore.

5. Nitric acid is produced from ammonia using the Ostwald process. The first stage of this process involves ammonia and oxygen from air:

$$4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$$

   Calculate the mass of oxygen needed to react completely with 3.4 kg of ammonia.

Use these relative atomic masses.

Element	H	N	C	O	Na	Fe	Cu
A_r	1	14	12	16	23	56	63.5

Reacting mass problems 2 – ANSWERS

1. Sodium reacts with oxygen to form sodium oxide: $4Na + O_2 \rightarrow 2Na_2O$

   Calculate the maximum mass of sodium dioxide that can be formed from 0.46 g of sodium.

   M_r of Na_2O = (2 × 23) + 16 = 62

   amount of Na = $\frac{0.46}{23}$ = 0.02 mol

   Mole ratio Na : Na_2O is 4 : 2 which simplifies to 2 : 1

   This means that $\frac{0.02}{2}$ × 1 = 0.01 mol of Na_2O forms

   Mass of Na_2O formed = 0.01 × 62 = 0.62 g

2. Ammonia is manufactured using the Haber process: $N_2 + 3H_2 \rightleftharpoons 2NH_3$

   Calculate the mass of ammonia formed if nitrogen reacts completely with 480 g of hydrogen.

   [Note: the double-headed arrow ⇌ shows that the reaction is reversible. You can ignore it here.]

   M_r of H_2 = 2 × 1 = 2 M_r of NH_3 = 14 + (3 × 1) = 17

   amount of H_2 = $\frac{480}{2}$ = 240 mol

   Mole ratio H_2 : NH_3 is 3 : 2

   This means that $\frac{240}{3}$ × 2 = 160 mol of NH_3 forms

   Mass of NH_3 formed = 160 × 17 = 2720 g

3. Copper(II) oxide can be reduced by heating with carbon: $2CuO + C \rightarrow 2Cu + CO_2$

   Calculate the mass of carbon needed to react completely with 7.95 g of copper(II) oxide.

   M_r of CuO = 63.5 + 16 = 79.5

   amount of CuO = $\frac{7.95}{79.5}$ = 0.1 mol

   Mole ratio CuO : C is 2 : 1

   This means that $\frac{0.1}{2}$ × 1 = 0.05 mol is needed

   Mass of C needed = 0.05 × 12 = 0.6 g

4. Iron is manufactured in a huge industrial furnace. One of the reactions that happens in the blast furnace involves iron(III) oxide and carbon monoxide:

$$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$$

(a) Calculate the mass of iron(III) oxide needed to produce 112 g of iron in this reaction.

M_r of $Fe_2O_3 = (2 \times 56) + (3 \times 16) = 160$

amount of Fe $= \frac{112}{56} = 2$ mol

Mole ratio Fe_2O_3 : Fe is 1 : 2

This means that $\frac{2}{2} \times 1 = 1$ mol of Fe_2O_3 is needed

Mass of Fe_2O_3 needed $= 1 \times 160 = 160$ g

(b) Use your answer to part (a) to calculate the mass of iron that can be made from 320 tonnes of iron(III) oxide.

Mass of iron $= \frac{320 \times 10^6 \text{g}}{160 \text{ g}} \times 112 = 2.24 \times 10^8 \text{g} = 224$ tonnes

If answer (a) is incorrect, allow value of 320 ÷ (answer a) × 112

(c) Iron ore is impure iron(III) oxide. A blast furnace produces 168 tonnes of iron from 320 tonnes of an iron ore. Use your answer to part (b) to calculate the percentage purity of this iron ore.

% purity $= \frac{\text{actual mass of substance obtained}}{\text{expected mass of substance obtained}} \times 100 = \frac{168 \text{ tonnes}}{224 \text{ tonnes}} \times 100$

= 75%

If answer (b) is incorrect, allow value of 168 ÷ (answer b) × 100

5. Nitric acid is produced from ammonia using the Ostwald process. The first stage of this process involves ammonia and oxygen from air:

$$4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$$

Calculate the mass of oxygen needed to react completely with 3.4 kg of ammonia.

M_r of $NH_3 = 14 + (3 \times 1) = 17$ M_r of $O_2 = 2 \times 16 = 32$

amount of $NH_3 = \frac{3.4 \times 10^3}{17} = 200$ mol

Mole ratio $NH_3 : O_2$ is 4 : 5

This means that $\frac{200}{4} \times 5 = 250$ mol of O_2 is needed

Mass of O_2 needed $= 250 \times 32 = 8\,000$ g (8 kg)