Moles Questions Mixed

1 Iron can be extracted from its ore by heating with carbon monoxide:

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

When 10.00 kg of iron ore, containing mostly Fe_2O_3, was heated with excess carbon monoxide 6.72 kg of iron was obtained. Determine the percentage Fe_2O_3 in the iron ore. *(Assume that no other compounds in the iron ore react with carbon monoxide).*

Convert kg to g

Number of moles of iron = $\frac{6.72 \times 1000}{55.85}$ = 120.3 mol

Number of moles of Fe_2O_3 = $\frac{120.3}{2}$ = 60.16 mol

Mass of Fe_2O_3 = 60.16 x (2x55.85 + 3x16.00) = 9608 g

Percentage iron in the iron ore = $\frac{9608}{10\,000}$ x 100 = 96.1%

Convert kg to g

2 Hydrogen peroxide decomposes rapidly in the presence of a catalyst such as MnO_2.

$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$$

Determine the concentration of the hydrogen peroxide solution (in mol dm^{-3}) if 50.0 cm^3 of the solution decomposes to form 1.00 dm^3 of oxygen, measured at 20 ^oC and 100 kPa.

P=100 kPa

Pressure in kPa and volume in dm^3 are a consistent set of units.

V=1.00 dm^3

n=?

R=8.31 J K^{-1} mol^{-1}

T=20+273 = 293 K

PV=nRT   n = $\frac{PV}{RT}$ = $\frac{100 \times 1}{8.31 \times 293}$ = 0.04107 mol

From the equation, the number of moles of H_2O_2 is 2 x the number of moles of O_2
Therefore the number of moles of H_2O_2 that decompose to form 0.04107 mol O_2 is 2 x 0.04107 = 0.0821 mol

concentration of hydrogen peroxide = $\frac{\text{number of moles}}{\text{volume}}$ = $\frac{0.0821}{(50.0/1000)}$ = 1.64 mol dm^{-3}

Convert volume to dm^3

3 Calculate the volume (in cm^3) of oxygen (measured at STP) produced when 25.0 cm^3 of 0.0180 mol dm^{-3} potassium manganate(VII) reacts with 30.0 cm^3 0.0250 cm^3 hydrogen peroxide solution in the presence of excess sulfuric acid, according to the equation:

$$2KMnO_4(aq) + 5H_2O_2(aq) + 3H_2SO_4(aq) \rightarrow 2MnSO_4(aq) + K_2SO_4(aq) + 5O_2(g) + 8H_2O(l)$$

Number of moles of $KMnO_4$ = 25.0/1000 x 0.0180 = 4.50×10^{-4} mol
Number of moles of H_2O_2 = 30.0/1000 x 0.0250 = 7.50×10^{-4} mol

There is enough information to work out the number of moles of 2 things so immediately think *limiting reactant*

5H_2O_2 and **2**$KMnO_4$ – to find the number of moles of $KMnO_4$ from the number of moles of H_2O_2 divide by 5 and multiply by 2

From the equation, 7.50×10^{-4} mol H_2O_2 react with $^2/_5$ x 7.5×10^{-4} mol $KMnO_4$ = 3.00×10^{-4} mol
The number of moles of $KMnO_4$ present is greater than this, therefore $KMnO_4$ is in excess and H_2O_2 is the limiting reactant.

Number of moles of oxygen = 7.50×10^{-4} mol

Molar volume of gas at STP is 22.7 dm^3 mol^{-1}

Volume measured at STP = 7.50×10^{-4} x 22.7 = 0.0170 dm^3

Therefore volume of oxygen in cm^3 is 0.0170 x 1000 = 17.0 cm^3

4 Zinc metal reacts with dilute hydrochloric acid according to the equation:

$$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$$

Calculate the volume (in cm^3) of hydrogen produced, measured at 22 ^oC and 9.88×10^4 Pa, if 5.00 g of zinc is reacted with 30.0 cm^3 of 2.00 mol dm^{-3} hydrochloric acid.

Number of moles of Zinc = 5.00/65.38 = 0.0765 mol
Number of moles of hydrochloric acid = 30.0/1000 x 2.00 = 0.0600 mol

From the equation, 0.0600 mol HCl react with 0.0600/2 = 0.0300 mol Zn
The number of moles of Zn present is greater than this, therefore Zn is in excess and HCl is the limiting reactant.

Number of moles of Hydrogen = 0.0600/2 = 0.0300 mol

P=9.88×10^4 Pa
V=?
n=0.0300 mol
R=8.31 J K^{-1} mol^{-1}
T=22+273 = 295 K

PV=nRT $\quad V = \frac{nRT}{P} = \frac{0.0300 \times 8.31 \times 295}{9.88 \times 10^4} = 7.44 \times 10^{-4}\ m^3$

Therefore volume of hydrogen in cm^3 is $7.44 \times 10^{-4} \times 10^6 = 744\ cm^3$

5 4.09 g of hydrated iron(II) sulfate ($FeSO_4.xH_2O$) is dissolved in water and made up to a total volume of 100.0 cm^3. 20.0 cm^3 of this solution is acidified and then reacted with 0.0200 mol dm^{-3} potassium manganate(VII) solution ($KMnO_4(aq)$). 29.40 cm^3 of $KMnO_4(aq)$ was required for exact reaction. Calculate the value of x in $FeSO_4.xH_2O$.

$$MnO_4^-(aq) + 5Fe^{2+}(aq) + 8H^+(aq) \rightarrow Mn^{2+}(aq) + 5Fe^{3+}(aq) + 4H_2O(l)$$

Number of moles of $KMnO_4$ = 29.40/1000 x 0.0200 = 5.88×10^{-4} mol

$KMnO_4$ dissolves in water to produce $K^+(aq)$ and $MnO_4^-(aq)$ ions, therefore this is the same as the number of moles of $MnO_4^-(aq)$

Number of moles of Fe^{2+} = 5 x 5.88×10^{-4} = 2.94×10^{-3} mol

Number of moles of Fe^{2+} in 100.0 cm^3 = 5 x 2.94×10^{-3} = 0.0147 mol

Only 20.0 cm^3 of the original 100.0 cm^3 was reacted with the $KMnO_4$.

Number of moles of $FeSO_4$ in 4.09 g = 0.0147 mol

There is 1 Fe^{2+} in each $FeSO_4$ unit

Mass of $FeSO_4$ in 4.09 g is 0.0147 x (55.85 + 32.07 + 4x16) = 2.23 g

Molar mass of $FeSO_4$

Mass of H_2O in 4.09 g of $FeSO_4.xH_2O$ = 4.09 – 2.23 = 1.86 g

Number of moles of water = 1.86/18.02 = 0.103 mol

Ratio of moles of water to number of moles of $FeSO_4$ = 0.103/0.0147 = 7.01

Value of x is 7

x will be a whole number

6 Pure chromium can be extracted from chromite ($FeCr_2O_4$) in the following series of reactions:

$4FeCr_2O_4 + 8Na_2CO_3 + 7O_2 \rightarrow 8Na_2CrO_4 + 2Fe_2O_3 + 8CO_2$ 1

$2Na_2CrO_4 + H_2SO_4 \rightarrow Na_2Cr_2O_7 + Na_2SO_4 + H_2O$ 2

$Na_2Cr_2O_7 + 2C \rightarrow Cr_2O_3 + Na_2CO_3 + CO$ 3

$Cr_2O_3 + 2Al \rightarrow Al_2O_3 + 2Cr$ 4

If 2.000 kg of pure chromium is obtained how much chromite was used?

The easiest way to do this is just to scale up from the mass of chromium present in a formula unit of chromite to the mass of chromite

The mass of chromium in each chromite unit is 2 x 52.00 = 104.00

M_r of chromite is 55.85 + 2x52.00 + 4x16.00 = 223.85

Mass of chromite used = $\frac{223.85}{104.00}$ x 2.000 = 4.305 kg

Alternative method:

Number of moles of chromium = $\frac{2.000 \times 1000}{52.00}$ = 38.46 mol

Only use the coefficients to work out number of moles ***within*** an equation – not between them – all the Na_2CrO_4 from equation 1 react in equation 2

This is produced from 38.46/2 = 19.23 mol Cr_2O_3

19.23 mol Cr_2O_3 is produced from 19.23 mol $Na_2Cr_2O_7$

19.23 mol $Na_2Cr_2O_7$ is produced from 2x19.23 mol Na_2CrO_4 = 38.46 mol Na_2CrO_4

38.46 mol Na_2CrO_4 is produced from 38.46/2 mol $FeCr_2O_4$ = 19.23 mol

The mass of 19.23 mol $FeCr_2O_4$ = 19.23 x 223.85 = 4305 g or 4.305 kg

7 1.12 g of hydrated copper nitrate ($Cu(NO_3)_2.xH_2O$) is dissolved in water and the solution made up to a total volume of 250.0 cm^3. 25.00 cm^3 of this solution is taken and excess potassium iodide solution added. The iodine liberated completely reacted with 23.20 cm^3 of 0.0200 mol dm^{-3} sodium thiosulfate solution. Calculate the value of x in $Cu(NO_3)_2.xH_2O$. The ionic equations for the reactions involved are:

$2Cu^{2+}(aq) + 4I^-(aq) \rightarrow 2CuI(s) + I_2(aq)$

$2S_2O_3^{2-}(aq) + I_2(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$

Number of moles of $S_2O_3^{2-}$ = 23.20/1000 x 0.0200 = 4.64×10^{-4} mol

Number of moles of I_2 = $4.64 \times 10^{-4}/2$ = 2.32×10^{-4} mol

Number of moles of Cu^{2+} in 25.00 cm^3 = 2 x 2.32×10^{-4} = 4.64×10^{-4} mol

Number of moles of Cu^{2+} in 250.0 cm^3 = 10 x 4.64×10^{-4} = 4.64×10^{-3} mol

Only 25.0 cm^3 of the original 250.0 cm^3 was reacted with the $KMnO_4$.

Number of moles of $Cu(NO_3)_2$ in 1.12 g = 4.64×10^{-3} mol

Mass of $Cu(NO_3)_2$ in 1.12 g is 4.64×10^{-3} x (63.55 + 2x14.01 + 6x16) = 0.870 g

Molar mass of $Cu(NO_3)_2$.

Mass of H_2O in 1.12 g of $Cu(NO_3)_2.xH_2O$ = 1.12-0.87 = 0.25 g

Number of moles of water = 0.25/18.02 = 0.0139 mol

Ratio of moles of water to number of moles of $Cu(NO_3)_2$ = 0.0139/4.64×10^{-3} = 2.99

Value of x is 3

x will be a whole number

8 1.020 g of magnesium was placed in a beaker and 50.00 cm^3 of 2.000 mol dm^{-3} hydrochloric acid added. The resulting solution was transferred to a volumetric flask and made up to a total volume of 100.0 cm^3 with water. 25.00 cm^3 of this solution was titrated against 0.1120 mol dm^{-3} sodium hydroxide solution and 34.30 cm^3 of the sodium hydroxide was required for neutralisation. Use this information to work out the relative atomic mass of magnesium to 2 decimal places. The relevant equations are:

$$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$$

$$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$$

This technique is called back titration. Excess hydrochloric acid is added to the magnesium. The magnesium reacts with some of the hydrochloric acid and then we can find out how much is left over by reacting it with sodium hydroxide solution. If we know how much hydrochloric acid was added originally and how much is left at the end we can work out how much reacted with the magnesium and hence how much magnesium was present.

Number of moles of NaOH = 34.30/1000 x 0.1120 = 3.8416×10^{-3} mol

More significant figures carried through – will be rounded at the end

Number of moles of HCl this reacts with = 3.8416×10^{-3} mol

Number of moles of HCl in 25.00 cm^3 = 3.8416×10^{-3} mol

Only 25.0 cm^3 of the 100.0 cm^3 was reacted with the NaOH

Number of moles of HCl in 100.0 cm^3 = 4 x 3.8416×10^{-3} = 1.5366×10^{-2} mol

Number of moles of HCl added to the Mg = 50.00/1000 x 2.000 = 0.1000 mol

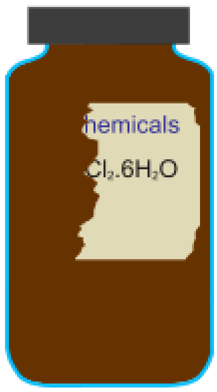
Number of moles of HCl that reacted with the Mg = 0.1000 - 1.5366×10^{-2} = 0.084634 mol

Number of moles of Mg that reacted with the HCl = 0.084634/2 = 0.042317 mol

1.020 g of Mg is therefore 0.042317 mol

Relative atomic mass = 1.020/0.042317 = 24.10

9 A bottle of a white crystalline salt was found in a cupboard. All that was left of the label is shown in the diagram. 5.000 g of the substance was dissolved in water and made up to a total volume of 50.00 cm^3.
10.00 cm^3 of this solution was reacted with 25 cm^3 of 2.0 mol dm^{-3} silver nitrate solution (this was an excess). The precipitate was filtered off, washed, dried and weighed. The total mass of precipitate formed was 1.410 g. Work out the element missing from the formula of the substance.
$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$



The precipitate is silver chloride

Moles of silver chloride = $\frac{1.410}{143.32}$ = 9.838×10^{-3} mol

This is the same as the number of moles of chloride ion in 10.00 cm^3 of solution
Number of moles of chloride ions in 50.00 cm^3 of solution is 5 x 9.838×10^{-3} = 4.919×10^{-2} mol

This is the number of moles of chloride ions in 5.000 g of the salt

We know that the formula involves 'Cl_2', therefore the number of moles of the compound in 5.000 g is $4.919 \times 10^{-2}/2$ = 2.460×10^{-2} mol

2 chloride ions per formula unit

2.460×10^{-2} mol has a mass of 5.000 g, therefore the molar mass is $\frac{5.000}{2.460 \times 10^{-2}}$ =203.33 g mol^{-1}

The formula is $MCl_2.6H_2O$, so if, the mass of '$Cl_2.6H_2O$' is subtracted, the molar mass of M is obtained: 203.33 – (2x35.45 + 6x18.02) = 24.31 g mol^{-1}

From the Periodic Table the element can then be identified as Mg.

10 When the nitrate of element **X** is heated it decomposes to form the solid oxide of **X**, nitrogen dioxide and oxygen.

Use the following data to work out the ratio (in terms of number of moles) of nitrogen dioxide to oxygen in the gas given off.

0.0865 g of the gas collected occupied a volume of 50.0 cm^3 at a temperature of 27 ^oC and a pressure of $9.98x10^4$ Pa.

$P = 9.98x10^4$ Pa
$V = 50.0x10^{-6} = 5.00x10^{-5}$ m^3
n=?
R=8.31 J K^{-1} mol^{-1}
T=27+273 = 300 K

PV=nRT $\quad n = \frac{PV}{RT} = \frac{9.98x10^4 \text{ x } 5.00x10^{-5}}{8.31x300} = 2.0016x10^{-3}$ mol

The gas is a mixture of x mol of NO_2 (M_r=46.01) and y mol of O_2 (M_r=32.00)

$x + y = 2.0016x10^{-3}$

The total mass of the sample of gas is 46.01x + 32.00y = 0.0865

$x = 2.00x10^{-3} – y$

$46.01(2.0016x10^{-3} – y) + 32.00y = 0.0865$

Rearranging: 14.01y=0.00559
$y=3.99x10^{-4}$
$x=1.60x10^{-3}$

The ratio between NO_2 and O_2 is thus 4:1