Chem Factsheet

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# Let EMMA Do Your Mole Calculations For You

After studying this Factsheet you should be able to successfully complete any calculation based on moles that you meet.

This Factsheet deals with how to get your calculation steps in the right order to get you from the problem to the answer. However, in order to do so, it is essential that you are able to calculate the number of moles of a substance in any given sample. These will usually be one of three types:

1. A given **mass** (e.g. **w** g) of the sample of **known relative molecular mass** (e.g. $\mathbf{M_r}$).

**Number of moles (n) in sample = w ÷ $\mathbf{M_r}$**

*e.g How many moles of $CaCO_3$ are present in a 2.735g sample?*

$M_r(CaCO_3) = 40.1 + 12.0 + 3(16.0) = 101.1$

➔ Number of moles in sample = 2.735 ÷ 101.1 = **0.02705**

2. A given **volume** (e.g. **V** $cm^3$) and **molar concentration** (e.g. **C** mol $dm^{-3}$) for a sample in solution form.

**Number of moles (n) in sample =** $\mathbf{\dfrac{C \times V}{1000}}$

*e.g How many moles of NaOH are present in a 27.3 $cm^3$ sample of solution with concentration 0.0820 mol $dm^{-3}$?*

Number of moles in sample = 0.0820 × 27.3 ÷ 1000 = $\mathbf{2.24 \times 10^{-3}}$

3. (a) A **volume** (e.g. **V** $m^3$), **temperature** (e.g. **T** K) and **pressure** (e.g. **P** Pa) for a sample in gaseous form [this may not apply to your syllabus – 3(b) may be used instead].

**Number of moles (n) in sample =** $\mathbf{\dfrac{PV}{RT}}$

*e.g How many moles of gas are present in a 2343 $cm^3$ sample at 300K and 95.0kPa?*

Volume in $m^3 = 2343 \div 1000000 = 2.343 \times 10^{-3}$
Pressure in Pa = 95 ×1000 = 95000

➔ Number of moles in sample = $\dfrac{95000 \times 2.343 \times 10^{-3}}{8.31 \times 300} = 0.0893$

(b) A **volume** (e.g. **V** $dm^3$) at **room temperature** and **pressure** for a sample in gaseous form [this may not apply to your syllabus – 3(a) may be used instead.

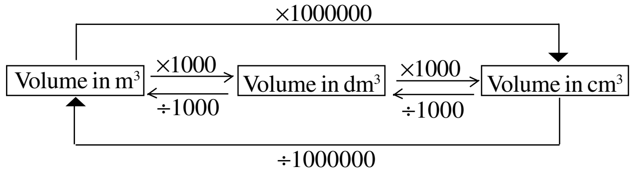
*e.g How many moles of gas are present in a 856 $cm^3$ sample at room temperature and pressure?*

**Number of moles (n) in sample =** $\mathbf{\dfrac{V}{24}}$

Volume in $dm^3 = 856 \div 1000 = 0.856$

➔ Number of moles in sample = $\dfrac{0.856}{24} = 3.57 \times 10^{-2}$

Note: Be sure that the units given are appropriate. In particular, gaseous pressures are usually given in kilopascals (kPa) – these would need to be converted to Pascals (Pa) by multiplying by 1000 before using 3(a). Similarly, volumes may need to be converted to $cm^3$, $dm^3$ or $m^3$ as appropriate for 2, 3(a) or 3(b). This can be done using:




Now you are confident that you can use (1)-(3) to calculate a number of moles it is time to apply this to real problems where information about one substance involved in a chemical reaction allows you to calculate information about any other reactant or product.

It is the *order* of the calculation steps which often causes problems but this can be remembered using the acronym EMMA. This is illustrated in the following table:

| | |
|---|---|
| **E** | **Write the balanced Equation for the reaction** |
| | *Decide which reactant or product you know enough about to calculate it's number of Moles (n). You will need :*<br>*(1) a formula to calculate $M_r$ and a mass (w/g)*<br>or *(2) a concentration, C (mol $dm^{-3}$) and volume, V($cm^3$) for a solution*<br>or *(3a) a pressure, P(Pa), a volume, V($m^3$) and a temperature, T(K) for a gas*<br>or *(3b) a volume, V($dm^3$) at room temperature and pressure for a gas* |
| **M** | **Calculate the number of Moles for that known substance** |
| | *Decide which reactant or product is the target of your calculation* |
| **M** | **Use the mole ratio from the balanced equation to calculate the number of Moles of the target substance relative to the number of moles of the known substance calculated in the previous step** |
| | Note : The equation is often given in the question. If not, ALWAYS attempt to write an equation because, even if you get it wrong, use of the wrong reacting ratio will usually cause you to lose only one of 4 or 5 marks. |
| **A** | **If required, convert this number of moles to the Answer required by the question – this may be a concentration, a volume, a mass, a % purity etc. In general this will be done using the relationships from (1), (2), (3a) or (3b).** |

***Note in this general scheme, and in the examples that follow, how one step in a calculation is always connected to the previous step.***

All that remains is to go through some worked examples and then try some examples for yourself.

***Example 1***
***25.0 $cm^3$ of 0.100M potassium hydroxide (KOH) reacts with 21.4 $cm^3$ of hydrochloric acid (HCl) to form potassium chloride (KCl) and water. Calculate the concentration of the hydrochloric acid in (a) mol $dm^{-3}$ (b) g $dm^{-3}$.***

Equation: $KOH(aq) + HCl(aq) \rightarrow KCl(aq) + H_2O(l)$

Moles of KOH $= \frac{CV}{1000} = \frac{0.100 \times 25.0}{1000} = 0.0025$

Moles of HCl = 0.0025 because the equation shows a 1:1 reaction

Answer (a): Concentration of HCl $= \frac{n \times 1000}{V}$

$= \frac{0.0025 \times 1000}{21.4} = 0.117 \text{ mol dm}^{-3}$

Answer (b): Concentration of HCl $= C \times M_r(HCl) = 0.117 \times 36.5$
$= 4.26 \text{ g dm}^{-3}$

***Example 2***
***When barium nitrate is heated it decomposes as follows:***
***$Ba(N0_3)_2(s) \rightarrow BaO(s) + 2NO_2(g) + ½O_2(g)$***
***Calculate the total volume, measured at (a) 298 K and 100 kPa or (b) room temperature and pressure, of gas which is produced by decomposing 5.00 g of barium nitrate.***

Equation: $Ba(NO_3)_2(s) \rightarrow BaO(s) + 2NO_2(g) + ½O_2(g)$

Moles of $Ba(NO_3)_2 = \frac{w}{M_r} = \frac{5.00}{137 + 2(14 + 3(16))} = 0.01916$

Moles of gas $= 0.01916 \times 2½$
$= 0.04789$

because the equation shows that 1 mole of $Ba(NO_3)_2$ produces 2 + ½ moles of gas in total

Answer (a): Volume of gas $= \frac{nRT}{P} = \frac{0.04789 \times 8.31 \times 298}{100000}$
$= 0.00119 m^3 = 1.19 dm^3$

Answer (b): Volume of gas $= n \times 24 = 0.04789 \times 24 = 1.15 \text{ dm}^3$

***Example 3***
***A sample of titanium(IV) chloride was reacted with water as shown in the following equation.***
***$TiCl_4(l) + 2H_2O(l) \rightarrow 4HCl(aq) + TiO_2(s)$***
***The reaction produced 250 $cm^3$ of a 1.50 M solution of hydrochloric acid. Calculate the mass of $TiCl_4$ used.***

Equation: $TiCl_4(l) + 2H_2O(l) \rightarrow 4HCl(aq) + TiO_2(s)$

Moles of HCl $= \frac{CV}{1000} = \frac{1.50 \times 250}{1000} = 0.375$

Moles of $TiCl_4 = \frac{0.375}{4} = 0.09375$

because the equation shows 4 moles of HCl are produced from only one mole of $TiCl_4$.

Answer: Mass of $TiCl_4 = n \times M_r(TiCl_4) = 0.09375 \times (45 + 4(35.5))$
$= \underline{17.5}$ g

***Example 4***
***A sample of impure magnesium metal weighing 1.238g was was dissolved in excess hydrochloric acid. 1167$cm^3$ of hydrogen gas was produced (a) at 98 kPa and 20$^0$C or (b) at room temperature and pressure.***

NB $1167cm^3 = 1.167dm^3 = 0.000167m^3$

Equation: $Mg(s) + 2HCI(aq) \rightarrow MgCI_2(aq) + H_2(g)$

(a) Moles of hydrogen $= \frac{PV}{RT}$

$= \frac{98000 \times 0.001167}{8.31 \times 293} = 0.04697$

Moles of magnesium = 0.0497 because the equation shows one mole of $H_2$ is produced from one mole of Mg

Answer: Mass of Mg in sample $= n \times M_r(Mg)$
$= 0.0497 \times 24.1 = 1.132g$

% purity of Mg $= \frac{\text{Mass of pure Mg in sample}}{\text{Mass of impure Mg sample}} \times 100$

$= \frac{1.132 \times 100}{1.238} = 91.4$

(b) Moles of hydrogen $= \frac{V}{24} = \frac{1.167}{24} = 0.0486$

Moles of magnesium = 0. 0486 because the equation shows one mole of $H_2$ is produced from one mole of Mg

Answer: Mass of Mg in sample $= n \times M_r(Mg)$
$= 0.0486 \times 24.1 = 1.171g$

% purity of Mg $= \frac{\text{Mass of pure Mg in sample}}{\text{Mass of impure Mg sample}} \times 100$

$= \frac{1.171 \times 100}{1.238} = 94.6$

***Example 5***
***Calculate the volume of 0.0200 mol $dm^{-3}$ potassium manganate(VII) solution, $KMnO_4$, that will react with 25.0$cm^3$ of acidified hydrogen peroxide, $H_2O_2$, which contains 1.92 $gdm^{-3}$. The reaction equation is:***
***$2MnO_4^- + 5H_2O_2 + 6H^+ \rightarrow 2Mn^{2+} + 8H_2O + 5O_2$***

Equation: $2MnO_4^- + 5H_2O_2 + 6H^+ \rightarrow 2Mn^{2+} + 8H_2O + 5O_2$

Moles of $H_2O_2 = \frac{C \times V}{1000} = \frac{(1.92 \div Mr(H_2O_2)) \times 25.0}{1000}$

$= \frac{(1.92 \div 34.0) \times 25.0}{1000} = 0.001412$

Moles of $KMnO_4 = \frac{0.001412 \times 2}{5} = 0.0005647$

because the equation shows 5 moles of $H_2O_2$ react with only 2 moles of $MnO_4^-$

Answer:

Volume of 0.02 mol $dm^{-3}$ $KMnO_4 = \frac{n}{C} \times 1000 = \frac{0.0005647 \times 1000}{0.0200}$
$= 28.2 \text{ cm}^3$

**Practice Questions**

Note : Hints are given for the first three examples but then you are on your own! Don't be put off if the examples seem unfamiliar – EMMA helps you do ANY such calculation.

1. The mineral dolomite is a double carbonate of magnesium and calcium, with the formula $CaMg(CO_3)_2$. When 1.200 g of an *impure* sample of dolomite was completely dissolved in an excess of hydrochloric acid, 0.450 g of carbon dioxide was given off. Calculate the percentage purity of the dolomite.

Equation: $CaMg(CO_3)_2 + 4HCl \rightarrow CaCl_2 + MgCl_2 + 2CO_2 + 2H_2O$

Moles of $CO_2$ =

Moles of $CaMg(CO_3)_2$ =

Answer: Mass of $CaMg(CO_3)_2$ in sample =

% purity of $CaMg(CO_3)_2$ =

2. When copper reacts with dilute nitric acid, gaseous nitrogen monoxide is formed as shown by the following equation:
$3Cu + 8HNO_3 \rightarrow 3Cu(NO_3)_2 + 4H_2O + 2NO$

Calculate the volume in $cm^3$ of nitrogen monoxide, measured at (a) 330 K and 98.0 kPa or (b) room temperature and pressure, which is formed when 1.25g of pure copper metal reacts completely with an excess of dilute nitric acid.

Equation: $3Cu + 8HNO_3 \rightarrow 3Cu(NO_3)_2 + 4H_2O + 2NO$

Moles of Cu =

Moles of NO =

Answer: (a) Vol of NO =
(b) Vol of NO =

3. A 1.40g sample of 90.0% pure iron was reacted with an excess of dilute sulphuric acid. All of the iron in the sample was converted into aqueous iron(II) ions and hydrogen was evolved. The solution formed was made up to $250cm^3$. A $25.0cm^3$ sample of this solution would react completely with how many $cm^3$ of a 0.0200 $moldm^{-3}$ solution of potassium dichromate(VI)).

Equations: $Fe + 2H^+ \rightarrow Fe^{2+} + H_2$ then
$Cr_2O_7^{2-} + 6Fe^{2+} + 14H^+ \rightarrow 2Cr^{3+} + 6Fe^{3+} + 7H_2O$

Moles of Fe =

Moles of $Cr_2O_7^{2-}$ =

Answer: Vol of 0.02M $Cr_2O_7^{2-}$ =

4. A $25.0cm^3$ sample of a solution of phosphoric acid [$H_3PO_4$] was found to react with exactly 19.8 $cm^3$ of a 0.135 mol $dm^{-3}$ solution of potassium hydroxide. Calculate the concentration of the phosphoric acid solution in $gdm^{-3}$.

5. The concentration of concentrated sulphuric acid can, after accurate dilution, be checked by titration. A sample of the concentrated sulphuric acid was analysed as follows:
(a) 10.0 $cm^3$ of sulphuric acid was diluted with water to make 500 $cm^3$ of solution.
(b) The diluted sulphuric acid was then titrated with aqueous sodium hydroxide, NaOH.
(c) In the titration, 25.0 $cm^3$ of 0.100 mol $dm^{-3}$ aqueous sodium hydroxide required 21.4 $cm^3$ of diluted sulphuric acid for neutralisation.

Calculate the concentration, in mol $dm^{-3}$, of the original conc. sulphuric acid.

6 A student reacted 1.45g of pure barium with $500cm^3$ of water. Calculate the concentration of the barium hydroxide solution produced and the volume of hydrogen gas measured at (a) room temperature and pressure or (b) 20°C and 100kPa.

7 Pure copper is needed for electrical purposes. The purity of a sample of copper can be found by reacting it with concentrated nitric acid, neutralising the resulting solution and treating it with excess potassium iodide. Iodine is liberated and this can be titrated with standard sodium thiosulphate solution. The sequence of reactions is:

$Cu(s) + 4H^+(aq) + 2NO_3^-(aq) \rightarrow Cu^{2+}(aq) + 2NO_2(g) + 2H_2O(l)$

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

$I_2(aq) + 2Na_2S_2O_3(aq) \rightarrow 2NaI(aq) + Na_2S_4O_6(aq)$

A copper foil electrode from an electric cell weighs 1.75 g. It was made into 250 $cm^3$ of a solution of copper(II) ions. To 25.0 $cm^3$ of this solution excess iodide ions were added, and the mixture titrated with 0.100 mol $dm^{-3}$ sodium thiosulphate solution ; 26.8 $cm^3$ was required. Calculate the percentage purity of the copper foil.

**Answers**
1. 78.5%
2. (a) $367cm^3$ or (b) 315 $cm^3$
3. Your answer should be 18.82 $cm^3$. If not, have you allowed for the % purity and / or the sample size?
4. 3.49 $gdm^{-3}$
5. 2.92 $moldm^{-3}$
6. 0.0211 $moldm^{-3}$ ; (a) $253cm^3$ (b) $257cm^3$
7. 97.2%

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