

Week 1 Revision

| | |
|---------------|---|
| Atom | Massive nucleus surrounded by cloud of very light electrons |
| Atomic number | Z ; number of protons in the nucleus of an atom. If number of protons = number of electrons then the atom is electrically neutral |
| Mass number | A ; the total number of protons and neutrons in the nucleus of an atom |

What are the numbers of protons, neutrons and electrons in:



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Relative atomic mass (A_r)

a.k.a. atomic weight or average atomic mass.

The average of the atomic masses of all the chemical element's isotopes as found in a particular environment, weighted by isotopic abundance.

Calculate the relative atomic mass of chlorine given that it consists of two isotopes:



$$\begin{aligned} A_r &= \frac{34.97 \times 75.91}{100} + \frac{36.98 \times 24.09}{100} \\ &= 26.55 + 8.89 \\ &= 35.44 \end{aligned}$$

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Percentage composition

The percentage composition is the proportion of individual elements to molecular mass.

Calculate the percentage composition of Mg in MgO:

$$\begin{aligned} &= \frac{A_r(\text{Mg})}{A_r(\text{MgO})} \times 100 \\ &= \frac{24.3}{(24.3 + 16)} \times 100 \\ &= 60.3\% \end{aligned}$$

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Molecular and Empirical formulae

Defined as the simplest whole number ratio of atoms of different elements in the compound.

e.g. Glucose

Molecular formula is $\text{C}_6\text{H}_{12}\text{O}_6$

Empirical formula is CH_2O

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To calculate an empirical formula:

1. List the constituent elements as a ratio
2. Obtain the corresponding % abundance (or mass)
3. Divide (2) above by the atomic weight (relative atomic mass)
4. Divide all values in (3) by the smallest value in (3)

Calculate the empirical formula of an oxide of lead which contains 86.6% lead

$$\begin{aligned} \text{Pb} &: \text{O} \\ = \frac{86.6}{207.2} &: \frac{13.4}{16.0} \\ = 0.418 &: 0.838 \\ = \frac{0.418}{0.418} &: \frac{0.838}{0.418} \\ = 1 &: 2 \end{aligned}$$

Thus, the empirical formula is PbO₂

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The empirical formula of certain carbohydrate is CH₂O. If the relative molecular mass of the compound is 180, what is its molecular formula?

$$M_r(\text{CH}_2\text{O}) = [12 + (2 \times 1) + 16] = 30$$

$$M_r(\text{compound}) = 180$$

$$\frac{M_r(\text{compound})}{M_r(\text{CH}_2\text{O})} = \frac{180}{30} = 6$$

Thus, the molecular formula is 6(CH₂O)

$$= \text{C}_6\text{H}_{12}\text{O}_6$$

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The Mole

It is the amount of substance which contains as many constituent entities as there are atoms in 12 g of ¹²₆C isotope.

A mole of any substance consists of Avogadro's Number (N_A) of the constituent entities of that substance.

Entities are typically molecules but may also be atoms, ions, or atomic particles.

Formulae for number of moles (n)

For mass $n = \frac{m}{M}$ where m = mass in gram; M = molar mass

For solutions $n = CV$ where C = concentration in molar (mol/L) units; V = volume in L

For gases $n = \frac{pV}{RT}$ where P = pressure in KPa; V = volume in litres; R = gas constant = 8.31; T = temperature in °K

For number of molecules $n = \frac{N}{N_A}$ where N = the number of molecules; N_A = Avogadro's Number = 6.023×10^{23}

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Calculate the number of moles (n) in:

1. 36 g of H₂O

$$n(\text{H}_2\text{O}) = m/M = 36 / 18 = 2 \text{ mol}$$

2. 84.0 g of nitrogen gas

$$n(\text{N}_2) = m/M = 84.0 / 28.0 = 3.00 \text{ mol}$$

3. 2 L of 0.1 M NaCl

$$n(\text{O}_2) = CV = 0.1 \times 2 = 0.2 \text{ mol}$$

4. 25 L of oxygen gas at 20°C and 100kpa pressure

$$n(\text{O}_2) = pV/RT = (100 \times 25) / [8.31 \times (273+20)] = 1.027 \text{ mol}$$

5. 4.1×10^{24} molecules of methane (CH₄)

$$n(\text{CH}_4) = N/N_A = (4.1 \times 10^{24}) / 6.023 \times 10^{23} = 6.81 \text{ mol}$$

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Electrovalencies and Chemical Formulae

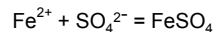
Chemical formulae must ensure that the overall positive charge of the cation balances that of the anion.

Write balanced chemical formulae for the following ionic substances:

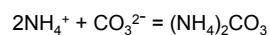
1. Magnesium chloride



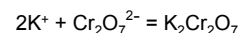
2. Iron (II) sulphate



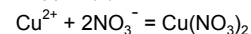
3. Ammonium carbonate



4. Potassium dichromate



5. Copper (II) nitrate



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Writing chemical equations

Full molecular equations for reactions

The steps involved are:

1. Write a word equation.
2. Write chemical formulae for every species and show the physical state *viz.*
solid = (s); gas = (g); liquid = (l); aqueous solution = (aq)
3. Put numbers in front of each formulae so that the number of atoms of each element is the same on the left hand side as the right hand side.

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Write balanced molecular equations for the following:

1. Hydrogen gas reacts with oxygen to form water

Word eqn.: hydrogen gas + oxygen gas → liquid water

Chemical formula: $\text{H}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow \text{H}_2\text{O}(\text{l})$

Balanced equation: $2\text{H}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{H}_2\text{O}(\text{l})$

2. Silver nitrate solution reacts with sodium chloride solution to form a precipitate of silver chloride and a solution of sodium nitrate

Word eqn.: Silver nitrate solution + sodium chloride solution → solid silver chloride + sodium nitrate solution

Chemical formula: $\text{AgNO}_3(\text{aq}) + \text{NaCl}(\text{aq}) \rightarrow \text{AgCl}(\text{s}) + \text{NaNO}_3(\text{aq})$

Balanced equation: $\text{AgNO}_3(\text{aq}) + \text{NaCl}(\text{aq}) \rightarrow \text{AgCl}(\text{s}) + \text{NaNO}_3(\text{aq})$

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3. Sodium carbonate solution reacts with dilute hydrochloric acid to form sodium chloride solution and water and carbon gas

Word eqn.: sodium carbonate + hydrochloric acid → sodium chloride + water + carbon gas

Chemical formula: $\text{Na}_2\text{CO}_3(\text{s}) + \text{HCl}(\text{aq}) \rightarrow \text{NaCl}(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$

Balanced equation: $\text{Na}_2\text{CO}_3(\text{aq}) + 2\text{HCl}(\text{aq}) \rightarrow 2\text{NaCl}(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$

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Ionic equations

These show the particles that were involved in the reaction and omit the spectator ions which have not reacted.

The steps involved are:

1. Write a balanced molecular equation.
2. Rewrite the equation listing all the aqueous species as separate ions.
3. Write the ionic equation after cancelling out the common or spectator ions.

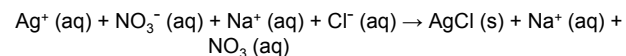
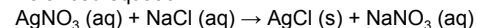
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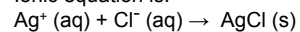
Write ionic equations for the following:

1. Silver nitrate solution + sodium chloride solution → solid silver chloride + sodium nitrate solution

Balanced equation:



Ionic equation is:

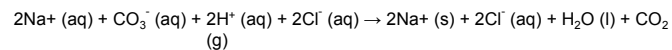
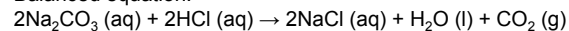


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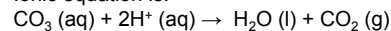
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2. sodium carbonate + hydrochloric acid → sodium chloride + water + carbon gas

Balanced equation:



Ionic equation is:



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Stoichiometry

Involves calculating amounts of products and reactants using chemical equations

The steps involved are:

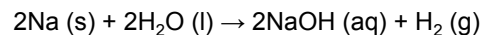
1. Write a balanced chemical equation for the reaction.
2. List all given data, including relevant units.
3. Convert the data given into moles using the relevant formula *e.g.* $n = m/M$; $n = CV$ *etc.*
4. Use the chemical equation to determine the mole ratio of the unknown quantity to the known quantity. This ratio enables calculation of the number of moles of the unknown quantity to be determined.
5. Finally, convert this number of moles back into the relevant units.

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Example of mass – mass stoichiometry

A sample of 5.6 grams of sodium reacts with water to produce sodium hydroxide solution and hydrogen gas. Calculate the mass of hydrogen gas that forms.



Mass of sodium = 5.6 g

$$n(\text{Na}) = m/M = 5.6/23.) = 0.243 \text{ mol}$$

Since 2 moles of Na gives 1 mole of H₂

$$\text{Then, } n(\text{H}_2) = \frac{1}{2} \times 0.243 = 0.122 \text{ mol}$$

$$\text{Mass of H}_2 = n(M) = 0.122 \times 2 = 0.244 \text{ g}$$

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Calculations involving excess reactants

More complicated if reactants are not present in their stoichiometric ratio.

Determine which reactant is completely consumed (called the limiting reactant) and which one is present in excess.

The limiting reactant determines how much product is formed.

A solution containing 1.5 g of AgNO₃ reacts with 40 mL of 0.20 M Magnesium chloride solution. What mass of silver chloride is precipitated?

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Step

Calculation

Write a balanced equation $2\text{AgNO}_3 \text{ (aq)} + \text{MgCl}_2 \text{ (aq)} \rightarrow 2\text{AgCl (s)} + \text{Mg(NO}_3)_2 \text{ (aq)}$

Write the information under the relevant chemicals in the equation. Calculate the mol quantities of the chemicals for which the data is given.

$$\begin{array}{ll} m = 1.5 \text{ g} & V = 40 \text{ mL} = 0.040 \text{ L} \\ M = 170 \text{ g mol}^{-1} & c = 0.20 \text{ M} \\ n = \frac{1.5}{170} & n = 0.040 \times 0.20 \\ & = 0.0080 \text{ mol} \end{array}$$

Determine if any reactant is in excess: Divide the moles of each reactant by its coefficient in the equation. The smallest of these answers is the limiting reactant. The moles of the limiting reactant is used to calculate the amount of product formed.

$$\frac{n(\text{AgNO}_3)}{\text{coeff. of AgNO}_3} = \frac{0.0088}{2} = 0.0044$$
$$\frac{n(\text{MgCl}_2)}{\text{coeff. of MgCl}_2} = \frac{0.0080}{1} = 0.0080$$

So AgNO₃ is the limiting reactant

Use the equation to calculate the amount, in mol, of the required substance:

$$\frac{n(\text{AgCl})}{n(\text{AgNO}_3)} = \frac{2}{2}$$

$$\frac{n(\text{unknown reagent})}{n(\text{limiting reagent})} = \frac{\text{coeff. of the unknown reagent}}{\text{coeff. of the limiting reagent}} \quad \text{So } n(\text{AgCl}) = n(\text{AgNO}_3) = 0.0088 \text{ mol}$$

Convert the amount, in mol, of the required substance into the appropriate quantity.

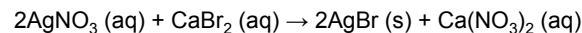
$$\text{So } m(\text{AgCl}) = 0.0088 \times 143.4$$
$$m(\text{AgCl}) = 1.3 \text{ g}$$

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Calculate the mass of silver bromide formed:
15.0 g of silver nitrate (aq) + 10.0 g of calcium bromide (aq)

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Calculate mole quantities:

$$n(\text{AgNO}_3) = \frac{m(\text{AgNO}_3)}{M(\text{AgNO}_3)} = \frac{15.0}{169.9} = 0.0883 \text{ mol}$$

$$n(\text{CaBr}_2) = \frac{m(\text{CaBr}_2)}{M(\text{CaBr}_2)} = \frac{10.0}{199.9} = 0.0500 \text{ mol}$$

The balanced equation shows that:

2 mol AgNO₃ reacts with 1 mol CaBr₂

How many moles of CaBr₂ will be reacted?

0.0883 AgNO₃ : $\frac{1}{2}(0.0883)$ CaBr₂

all the AgNO₃ will be consumed.

AgNO₃ is the limiting reactant; CaBr₂ is in excess

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To calculate the amount of silver bromide formed:

$$\frac{n(\text{AgBr})}{n(\text{AgNO}_3)} = \frac{1}{1}$$

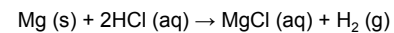
$$\begin{aligned}n(\text{AgBr}) &= n(\text{AgNO}_3) \\ &= 0.0883 \text{ mol}\end{aligned}$$

$$\begin{aligned}m(\text{AgBr}) &= n(\text{AgBr}) \times M(\text{AgBr}) \\ &= 0.0883 \times 187.8 \\ &= 16.6 \text{ g}\end{aligned}$$

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Magnesium reacts with hydrochloric acid according to the equation:



If 10.0 g of magnesium reacts completely, calculate:

a. The mass of magnesium chloride that forms.

$$10 \text{ g Mg} = 10/24.312 = 0.411 \text{ mol}$$

$$\frac{n(\text{Mg})}{n(\text{MgCl})} = \frac{1}{1}$$

$$\begin{aligned}n(\text{Mg}) &= n(\text{MgCl}) \\ &= 0.411 \text{ mol}\end{aligned}$$

$$\begin{aligned}m(\text{MgCl}) &= n(\text{MgCl}) \times M(\text{MgCl}) \\ &= 0.411 \times 59.765 \\ &= 24.56 \text{ g}\end{aligned}$$

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b. The mass of hydrogen that forms.

$$10 \text{ g mol Mg} = 10/24.312 = 0.411 \text{ mol}$$

$$\frac{n(\text{Mg})}{n(\text{H})} = \frac{1}{1}$$

$$\begin{aligned}n(\text{Mg}) &= n(\text{H}) \\ &= 0.411 \text{ mol}\end{aligned}$$

$$\begin{aligned}m(\text{H}_2) &= n(\text{H}_2) \times M(\text{H}_2) \\ &= 0.411 \times 2 \\ &= 0.822 \text{ g}\end{aligned}$$

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