

Dr Clays A-level Chemistry

UNIT 1 TOPIC 2

AMOUNT OF SUBSTANCE

Dr Chris Clay
http://drclays-alevelchemistry.com/

Unit 1 Topic 2 – Amount of Substance

Exercise 1 – Avogadro's Number and reacting masses

1. Calculate the number of moles present in each of the following cases:	2. Calculate the mass of substance present in the following cases:	3. Calculate the relative molecular mass of the following substances and suggest a possible identity of each substance:
a) 2.3 g of Na	a) 0.05 moles of Cl_2	a) 0.015 moles, 0.42 g
b) 2.5 g of O_2	b) 0.125 moles of KBr	b) 0.0125 moles, 0.50 g
c) 240 kg of CO_2	c) 0.075 moles of $Ca(OH)_2$	c) 0.55 moles, 88 g
d) 12.5 g of $Al(OH)_3$	d) 250 moles of Fe_2O_3	d) 2.25 moles, 63 g
e) 5.2 g of PbO_2	e) 0.02 moles of $Al_2(SO_4)_3$	e) 0.00125 moles, 0.312 g

4. Calculate the number of particles in the following substances:

a) 0.025 moles b) 2.5 g of CO_2 c) 5.0 g of Pb d) 100 g of N_2

5. Calculate the mass of the following substances:

a) 2.5×10^{23} molecules of N_2

b) 1.5×10^{24} molecules of CO_2

c) 2×10^{20} atoms of Mg

Reacting Masses

6. Calculate the mass of H_2O required to react completely with 5.0 g of $SiCl_4$:

$SiCl_4 + 2H_2O \rightarrow SiO_2 + 4HCl$

7. Calculate the mass of phosphorus required to make 200 g of phosphine, PH_3, by the reaction:

$P_4(s) + 3NaOH(aq) + 3H_2O(l) \rightarrow 3NaH_2PO_2(aq) + PH_3(g)$

8. Lead (IV) oxide reacts with concentrated hydrochloric acid as follows:

$PbO_2(s) + 4HCl(aq) \rightarrow PbCl_2(s) + Cl_2(g) + 2H_2O(l)$

What mass of lead chloride would be obtained from 37.2g of PbO_2, and what mass of chlorine gas would be produced?

9. When copper (II) nitrate is heated, it decomposes according to the following equation:

$2Cu(NO_3)_2(s) \rightarrow 2CuO(s) + 4NO_2(g) + O_2(g)$.

When 20.0g of copper (II) nitrate is heated, what mass of copper (II) oxide would be produced? What mass of NO_2 would be produced?

10. A blast furnace can produce about 700 tonnes of iron a day. How much iron (III) oxide will be consumed? Assuming coke is pure carbon, how much coke would be needed to produce the necessary carbon monoxide?

$Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(l) + 3CO_2(g)$

$2C(s) + O_2(g) \rightarrow 2CO(g)$

Atom Economy

11. Calculate the percentage atom economy of the following processes:

a) the production of iron in the blast furnace:
$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$

b) the production of titanium:
$TiCl_4 + 4Na \rightarrow Ti + 4NaCl$

c) the production of glass from sand:
$SiO_2 + 2NaOH \rightarrow Na_2SiO_3 + H_2O$

12. Calculate the atom economy of each of the following methods of producing iron and decide which is the most efficient process:

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

b) $Fe_2O_3 + 3H_2 \rightarrow 2Fe + 3H_2O$

c) $Fe_2O_3 + 2Al \rightarrow 2Fe + Al_2O_3$

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Exercise 2 - solutions

Using molarities and concentrations

1. Calculate the number of moles of H_2SO_4 in 50 cm^3 of a 0.50 $moldm^{-3}$ solution.
2.
3. Calculate the number of moles of $FeSO_4$ in 25 cm^3 of a 0.2 $moldm^{-3}$ solution.

4. Calculate the mass of $KMnO_4$ in 25 cm^3 of a 0.02 $moldm^{-3}$ solution.

5. Calculate the mass of $Pb(NO_3)_2$ in 30 cm^3 of a 0.1 $moldm^{-3}$ solution.

6. What is the molarity of 1.06g of H_2SO_4 in 250 cm^3 of solution?

7. What is the molarity of 15.0 g of $CuSO_4.5H_2O$ in 250 cm^3 of solution?

8. What volume of a 0.833 $moldm^{-3}$ solution of H_2O_2 will be required to make 250 cm^3 of a 0.100 $moldm^{-3}$ solution?

9. What volume of a 0.50 $moldm^{-3}$ solution of HCl will be required to make 100 cm^3 of a 0.050M solution?

10. How many moles of NaCl are there in 25 cm^3 of a 50 gdm^{-3} solution?

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Exercise 3 - Ideal Gas Equation

Remember: R = 8.31 $JK^{-1}mol^{-1}$, 0 K = -273 °C

1. Calculate the volume occupied by one mole of a gas at 25 °C and 100 kPa.
2. Calculate the pressure of a gas given that 0.2 moles of the gas occupy 10 dm^3 at 20 °C.
3. Calculate the temperature of a gas if 0.5 moles occupy 1.2 dm^3 at a pressure of 200 kPa.
4. Calculate the mass of a sample of carbon dioxide which occupies 20 dm^3 at 27 °C and 100 kPa.
5. Calculate the relative molecular mass of a gas if a 500 cm^3 sample at 20 °C and 1 atm has a mass of 0.66 g.
6. At 25 °C and 100 kPa a gas occupies a volume of 20 dm^3. Calculate the new temperature of the gas if
   a) the volume is decreased to 10 dm^3 at constant pressure.
   b) the pressure is decreased to 50 kPa at constant volume.
7. 10.0 g of calcium nitrate is heated at 100 kPa and a temperature of 300 °C, at which temperature it fully decomposes. Calculate

   a) the volume of nitrogen dioxide evolved

   b) the volume of oxygen evolved

   c) the total volume of gas evolved

   Equation: $2Ca(NO_3)_2(s) \rightarrow 2CaO(s) + 4NO_2(g) + O_2(g)$

8. Calculate the volume of oxygen produced at 298 K and 100 kPa by the decomposition of 30 cm^3 of 0.1 $moldm^{-3}$ hydrogen peroxide.

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

9. Lead (IV) oxide dissolves in concentrated hydrochloric acid according to the following equation: $PbO_2(s) + 4HCl(aq) \rightarrow PbCl_2(s) + Cl_2(g) + 2H_2O(l)$

   Starting with 37.2 g of lead (IV) oxide, calculate:

   a) the volume of 12 $moldm^{-3}$ HCl needed to completely dissolve it

   b) the mass of $PbCl_2$ produced

   c) the volume of chlorine produced at 298 K and 100 kPa.

10. What mass of magnesium, and what volume of 2.0 $moldm^{-3}$ hydrochloric acid, will be required to produce 100 cm^3 of hydrogen gas at 298 K and 100 kPa?

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

11. 0.52 g of sodium was added to 100 cm^3 of water. Calculate:

    a) The volume of hydrogen evolved at 298 K and 100 kPa

    b) The concentration of the sodium hydroxide solution produced, assuming the volume of water does not change.

    Equation: $2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$

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Exercise 4 - empirical and molecular formulae

1. A compound contains C 62.08%, H 10.34% and O 27.58% by mass. Find its empirical formula and its molecular formula given that its relative molecular mass is 58.

2. Find the empirical formula of the compound containing C 22.02%, H 4.59% and Br 73.39% by mass.

3. A compound containing 85.71% C and 14.29% H has a relative molecular mass of 56. Find its molecular formula.

4. A compound containing 84.21% carbon and 15.79% hydrogen by mass has a relative molecular mass of 114. Find its molecular formula.

5. Analysis of a hydrocarbon showed that 7.8 g of the hydrocarbon contained 0.6 g of hydrogen and that the relative molecular mass was 78. Find the molecular formula of the hydrocarbon.

6. 3.36 g of iron join with 1.44 g of oxygen in an oxide of iron. What is the empirical formula of the oxide?

7. What is the percentage composition of $SiCl_4$?

8. What is the mass of sulphur in 1 tonne of H_2SO_4?

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Exercise 5 – formulae, equations and ionic equations

A: Deduce the formulae of the following compounds:

1.	Sodium chloride	2.	Aluminium chloride
3.	Ammonium sulphate	4.	Magnesium nitrate
5.	Magnesium oxide	6.	Copper (II) hydroxide
7.	Aluminium oxide	8.	Sodium carbonate
9.	Copper (I) oxide	10.	Copper (II) oxide
11.	Aluminium sulphate	12.	Lead (II) sulphide
13.	Lead (IV) oxide	14.	Calcium nitride

B: Write out the full stoichiometric and ionic equations for the following reactions:

1. When aqueous magnesium chloride is added to aqueous silver nitrate, a white precipitate is formed.
2. When aqueous sodium hydroxide is added to aqueous aluminium sulphate, a white precipitate is formed.
3. When aqueous barium chloride is treated with dilute sodium sulphate, a white precipitate is formed.
4. Dilute sulphuric acid is neutralised by sodium hydroxide solution.
5. A pale blue precipitate is formed on slow addition of potassium hydroxide solution to copper (II) sulphate solution.
6. A white precipitate is formed when dilute hydrochloric acid is added to a solution of lead (II) nitrate.
7. When dilute calcium chloride is mixed with sulphuric acid, a white precipitate is formed.
8. Calcium carbonate dissolves in dilute hydrochloric acid with the evolution of a colourless gas.
9. When dilute sulphuric acid is added to sodium carbonate solution, a gas is given off.
10. When aqueous calcium chloride is mixed with aqueous sodium carbonate, a white precipitate is formed.
11. Ammonia gas dissolves in dilute nitric acid.

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Topic 2 Exercise 6 – more complex calculations

1. Succinic acid has the formula $(CH_2)_n(COOH)_2$ and reacts with dilute sodium hydroxide as follows:
$(CH_2)_n(COOH)_2 + 2NaOH \rightarrow (CH_2)_n(COONa)_2 + 2H_2O$

   2.0 g of succinic acid were dissolved in water and the solution made up to 250 cm^3. This solution was placed in a burette and 18.4 cm^3 was required to neutralise 25 cm^3 of 0.1 $moldm^{-3}$ NaOH. Deduce the molecular formula of the acid and hence the value of n.

2. Sodium carbonate exists in hydrated form, $Na_2CO_3.xH_2O$, in the solid state. 3.5 g of a sodium carbonate sample was dissolved in water and the volume made up to 250 cm^3. 25.0 cm^3 of this solution was titrated against 0.1 $moldm^{-3}$ HCl and 24.5 cm^3 of the acid were required. Calculate the value of x given the equation:

   $Na_2CO_3 + 2HCl \rightarrow 2NaCl + CO_2 + H_2O$

3. 25 cm^3 of a sample of vinegar (CH_3COOH) was pipetted into a volumetric flask and the volume was made up to 250 cm^3. This solution was placed in a burette and 13.9 cm^3 were required to neutralise 25 cm^3 of 0.1 $moldm^{-3}$ NaOH. Calculate the molarity of the original vinegar solution and its concentration in gdm^{-3}, given that it reacts with NaOH in a 1:1 ratio.

4. 2.5 g of a sample of impure ethanedioic acid, $H_2C_2O_4.2H_2O$, was dissolved in water and the solution made up to 250 cm^3. This solution was placed in a burette and 21.3 cm^3 were required to neutralise 25 cm^3 of 0.1 $moldm^{-3}$ NaOH. Given that ethanedioic acid reacts with NaOH in a 1:2 ratio, calculate the percentage purity of the sample.

5. A toilet cleaner containing sodium hydrogensulphate, $NaHSO_4$ is believed to have been contaminated. 5.678 g of the sample were dissolved in water and the solution was made up to 250 cm^3. This solution was placed in a burette and 23.1 cm^3 of it were required to neutralise 25 cm^3 of 0.1 $moldm^{-3}$ sodium hydroxide.

   Calculate the percentage purity of the sample given that the species react in a 1:1 ratio.

6. When silicon tetrachloride is added to water, the following reaction occurs:

   $SiCl_4(l) + 2H_2O(l) \rightarrow SiO_2(s) + 4HCl(aq)$

   1.2 g of impure silicon tetrachloride was dissolved in excess water, and the resulting solution was made up to 250 cm^3. A 25 cm^3 portion of the solution was then titrated against 0.10 $moldm^{-3}$ sodium hydroxide, and 18.7 cm^3 of the alkali were required. What was the percentage purity of the silicon tetrachloride?

7. 13.2 g of a sample of zinc sulphate, $ZnSO_4.xH_2O$, was strongly heated until no further change in mass was recorded. On heating, all the water of crystallisation evaporated as follows:
$ZnSO_4.xH_2O \rightarrow ZnSO_4 + xH_2O$.

   Calculate the number of moles of water of crystallisation in the zinc sulphate sample given that 7.4 g of solid remained after strong heating.