20 Key Calculations

1. Relative Formula Mass
2. Concentration (g/dm^3)
3. Moles to Particles
4. Moles Triangle
5. Concentration (mol/dm^3)
6. Converting Concentration
7. Titration Calculation
8. Empirical Formula from Molecular Formula
9. Molecular Formula from Empirical Formula
10. Empirical Formula from Reacting Masses
11. Empirical Formula from %composition
12. Conservation of Mass
13. Reacting Masses
14. Limiting Reagent
15. % Yield
16. Atom Economy
17. Gas Volume
18. Isotope Calculation
19. R_f Value
20. Bond Enthalpy

1-Relative Formula Mass

The relative formula mass (RFM) is calculated by adding together the atomic masses of all the atoms shown in the formula.

Example: Calculate the relative formula mass of ammonia, NH_3. The relative atomic masses are: H=1 and N=14)

RFM =14 + (3x1)=17.

You try:

Bronze: Calculate the relative formula mass of O_2 (The relative atomic mass of O=16)

Silver: Calculate the relative formula mass of $NaNO_3$ (The relative atomic mass of Na=23, N=14, O=16)

Gold: Calculate the relative formula mass of $Mg(OH)_2$ (The relative atomic mass of Mg = 24, O=16, H=1)

1-Relative Formula Mass - Answers

Bronze: Calculate the relative formula mass of O_2 (The relative atomic mass of O=16)

RFM= 14 + (3x1)=17

Silver: Calculate the relative formula mass of $NaNO_3$ (The relative atomic mass of Na=23, N=14, O=16)

RFM+ 23 + 14 + (3x16) =62

Gold: Calculate the relative formula mass of $Mg(OH)_2$ (The relative atomic mass of Mg = 24, O=16, H=1)

RFM = 24+ 2(16+1)=58

1-Calculating Relative Formula Mass

Q1. Calculate the relative formula mass of water, H_2O.

(Relative atomic masses: H = 1.0, O = 16)

= (1x2) + 16 =18

Q2. Calculate the relative formula mass of iron chloride, $FeCl_3$.
(Relative formula masses: Cl = 35.5, Fe = 56)

= 56 + (35.5x3) =162.5

Q3. Calculate the relative formula mass of copper chloride, $CuCl_2$.
(Relative atomic masses: Cu = 63.5, Cl = 35.5)

= 63.5 + (35.5x2) = 134.5

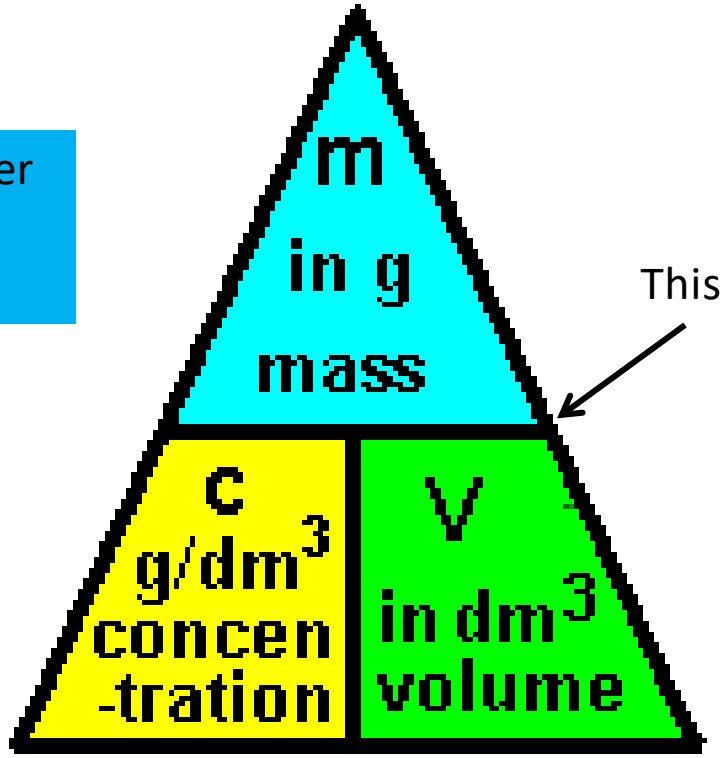
Q4. Calculate the relative formula mass of calcium chloride, $CaCl_2$.
(Relative atomic masses: Ca = 40; Cl = 35.5)

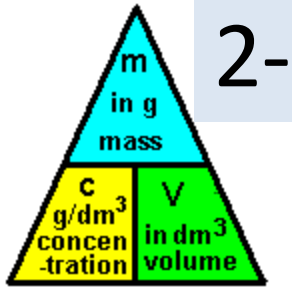
= 40 + (35.5x2) =111

2-Calculating Concentration

$$\text{Concentration} = \frac{\text{mass}}{\text{volume}}$$

To use this triangle, cover up the part you are looking for.





2-Calculating Concentration

1000 cm^3 = 1 dm^3

$$\text{Concentration} = \frac{\text{mass}}{\text{volume}}$$

Example:

What is the concentration of a solution made from 25g of sodium hydroxide and 100 dm^3 of water?

$$\text{Concentration} = \frac{25}{100} = 0.25 g/dm^3$$

You try:

1. Calculate the concentration of a solution made from 10g of sodium hydroxide and 200 dm^3 of water.
2. What is the concentration of a solution made from 2.5g of sodium chloride and 12 dm^3 of water?
3. How many grams are needed to make 500 dm^3 of solution of potassium hydroxide with a concentration of 5 g/dm^3 ?
4. What volume of water is needed to make a solution 7g/dm^3 solution from 2g of sodium carbonate?
5. What is the concentration in g/dm^3 of a solution made from 0.9g of sugar and 25 cm^3 of water?

2-Calculating Concentration - Answers

You try:

1. Calculate the concentration of a solution made from 10g of sodium hydroxide and 200 dm^{-3} of water.

$$\text{Concentration} = \frac{10}{200} = 0.05 g/dm^3$$

2. What is the concentration of a solution made from 2.5g of sodium chloride and 12 dm^3 of water?

$$\text{Concentration} = \frac{2.5}{12} = 0.21 g/dm^3$$

3. How many grams are needed to make 500 dm^3 of solution of potassium hydroxide with a concentration of 5 g/dm^3 ?

$$\text{Mass} = \text{concentration} \times \text{volume} = 5 \times 500 = 2500 g$$

4. What volume of water is needed to make a solution 7g/dm^3 solution from 2g of sodium carbonate?

$$\text{Volume} = \frac{\text{mass}}{\text{concentration}} = \frac{2}{7g} = 0.285 dm^3$$

5. What is the concentration in g/dm^3 of a solution made from 9g of sugar and 25 cm^3 of water?

$$\text{Concentration} = \frac{9}{25} \text{x} 1000 = 360 g/dm^3$$

3-Using Avogadro's Constant

You will be given this constant on your exam

Calculating the number of particles:

To calculate the number of particles, multiply the number of moles by 6.0×10^{23}.

How many particles?

1. 2 moles of carbon

$$\text{particles} = \text{moles} \times 6.0x10^{23} = 2 \times 6.0 \times 10^{23} = 1.2 \times 10^{24}$$

2. 0.04 moles of CO_2

$$\text{particles} = \text{moles} \times 6.0x10^{23} = 0.04 \times 6.0 \times 10^{23} = 2.4 \times 10^{22}$$

3. 0.5 moles of HCl

$$\text{particles} = \text{moles} \times 6.0x10^{23} = 0.5 \times 6.0 \times 10^{23} = 3.0 \times 10^{23}$$

3-Using Avogadro's Constant

You will be given this constant on your exam

Calculating the number of moles:

To calculate the number of moles, divide the number of particles by 6.0×10^{23}.

How many moles?

1. 1000 molecules of oxygen

$$\text{moles} = \frac{\text{particles}}{6\times10^{23}} = \frac{1000}{6\times10^{23}} = 1.7\times10^{-21}$$

2. 2,000,000 molecules of hydrogen

$$\text{moles} = \frac{\text{particles}}{6\times10^{23}} = \frac{2{,}000{,}000}{6\times10^{23}} = 3.3\times10^{-18}$$

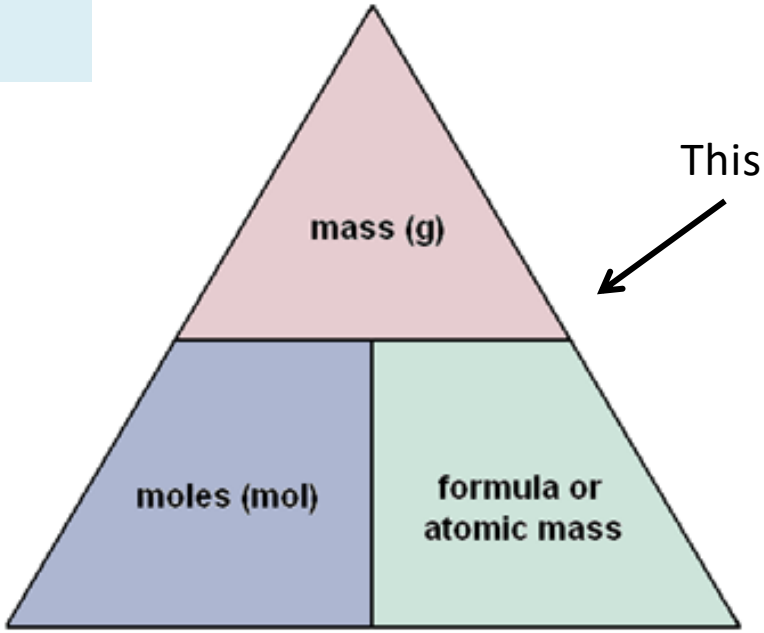
3. 3×10^{25} atoms of helium

$$\text{moles} = \frac{\text{particles}}{6\times10^{23}} = \frac{3\times10^{25}}{6\times10^{23}} = 50$$

4-The Moles Triangle

$$\text{moles} = \frac{\text{mass}}{\text{RFM/RAM}}$$

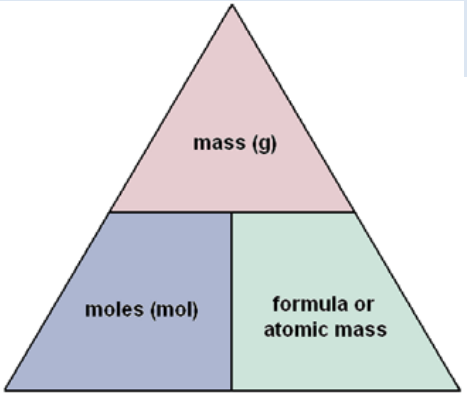
To use this triangle, cover up the part you are looking for.



This line means divide

This line means multiply

4-Using the Moles Triangle:



You have to learn this triangle

Bronze: How many moles in . . .?

1. 12g of Mg (RAM of Mg=24)
2. 2g of H_2 (RAM of H=1)
3. 51g of NH_3 (RAM of H=1, N=14)

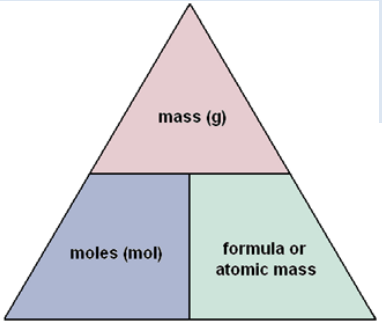
Silver: How many grams in . . .?

1. 1 mole of carbon (RAM of C=12)
2. 0.2 moles of CO2 (RAM of C=12, O=16)
3. 0.5 moles of HCl (RAM of H=1, Cl=35.5)

Gold: How many particles in . . .?

1. 3g of Mg (RAM of Mg =24)
2. 0.5g of Water, H_2O (RAM of H=1, O=16)

4-Using the Moles Triangle:



Bronze: How many moles in . . .?

1. 12g of Mg (RAM of Mg=24)

$$\text{moles} = \frac{\text{mass}}{\text{RAM}} = \frac{12}{24} = 0.5$$

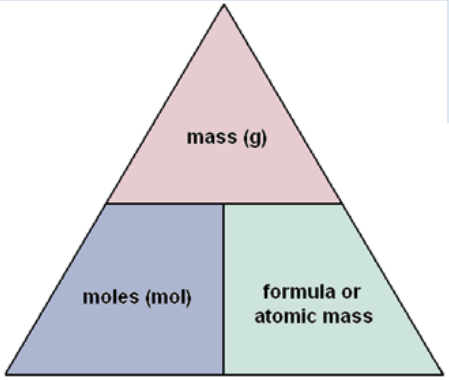
2. 2g of H_2 (RAM of H=1)

$$\text{moles} = \frac{\text{mass}}{\text{RFM}} = \frac{2}{2} = 1$$

3. 51g of NH_3 (RAM of H=1, N=14)

$$\text{moles} = \frac{\text{mass}}{\text{RFM}} = \frac{51}{17} = 3$$

4-Using the Moles Triangle:



Silver: How many grams in . . .?

1. 1 mole of carbon (RAM of C=12)

$$\text{mass} = \text{moles} \times \text{RAM} = 1 \times 12 = 12g$$

2. 0.2 moles of CO_2 (RAM of C=12, O=16)

$$\text{mass} = \text{moles} \times \text{RFM} = 0.2 \times 44 = 8.8g$$

3. 0.5 moles of HCl (RAM of H=1, Cl=35.5)

$$\text{mass} = \text{moles} \times \text{RFM} = 0.5 \times 36.6 = 18.25g$$

4-Using the Moles Triangle:

Gold: How many particles in . . .?

1. 3g of Mg (RAM of Mg =24)

Step 1: Calculate moles:

$$\text{moles} = \frac{\text{mass}}{\text{RAM}} = \frac{3}{24} = 0.125$$

Step 2: Use Avogadro's Constant to calculate particles

$$\text{particles} = \text{moles} \times 6.0\text{x}10^{23} = 0.125 \times 6.0 \times 10^{23} = 7.5 \times 10^{22}$$

2. 0.5g of Water, H_2O (RAM of H=1, O=16)

$$\text{moles} = \frac{\text{mass}}{\text{RFM}} = \frac{0.5}{18} = 0.028$$

$$\text{particles} = \text{moles} \times 6.0\text{x}10^{23} = 0.027 \times 6.0 \times 10^{23} = 1.67 \times 10^{22}$$

4-Exam Questions

Q3. 1.27 g of copper were produced in an experiment. Calculate the number of moles of copper, Cu, produced in this experiment. (Relative atomic mass: Cu = 63.5)

(1)

..... 0.02 .....

amount of copper produced = ... mol

Q2. Glucose has the formula $C_6H_{12}O_6$. Calculate the number of moles in a 0.25 g sample.
(relative atomic masses: H=1, C=12, O=16)

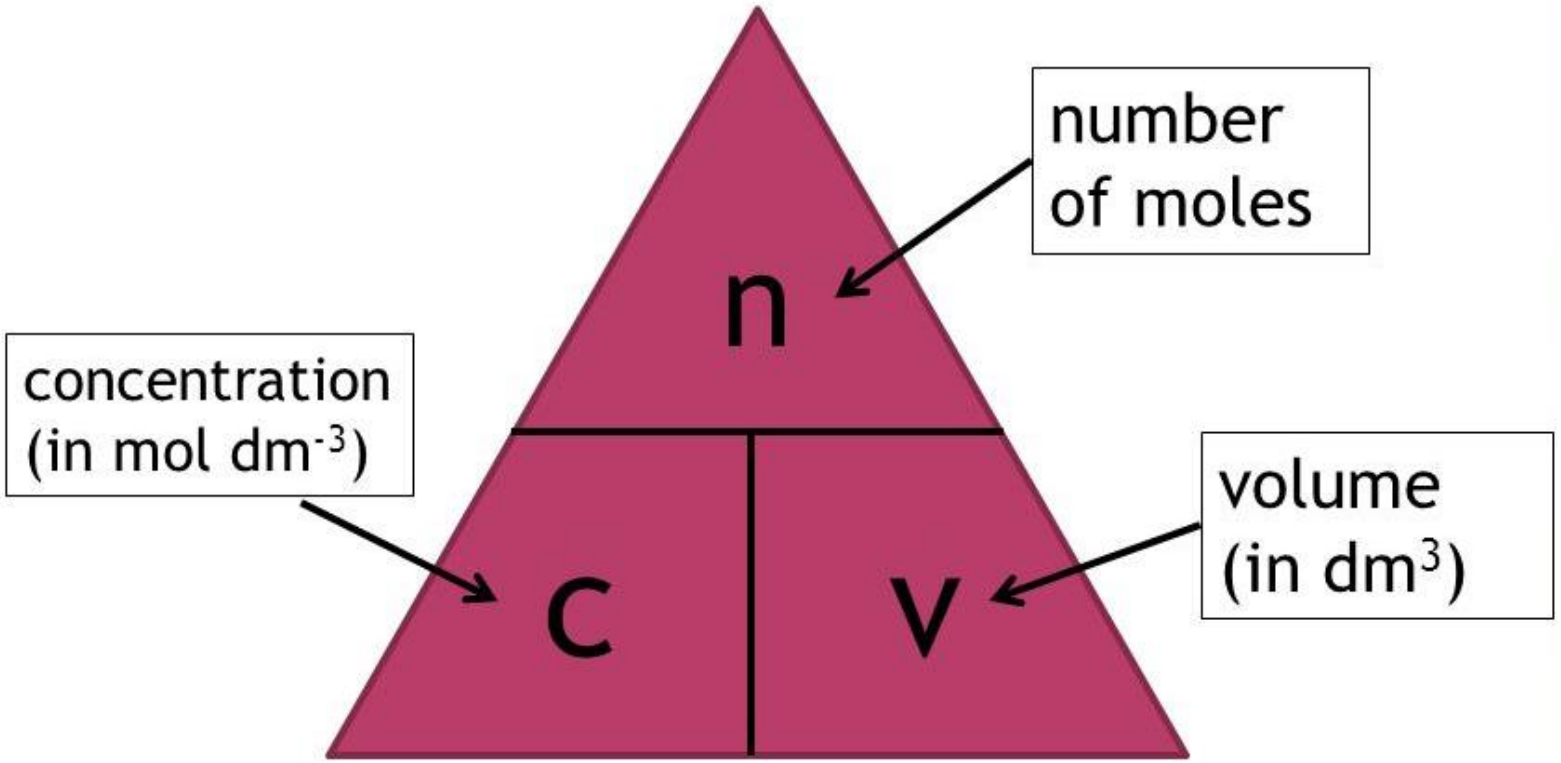
RFM = 180

Moles = 0.0014

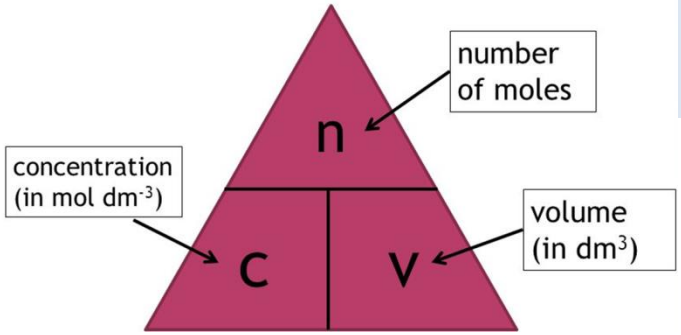
5-The Molarity Triangle

You have to learn this triangle

Concentration in moles/dm^3 (molarity, M) can be calculated using the following triangle:



5-Using the Molarity Triangle:



Bronze: What is the concentration in moles/dm^3 of:

1. 0.5 moles of hydrochloric acid in 1 dm^3 of water
2. 1.5 moles of sodium carbonate in 0.5 dm^3 of water

You have to learn this triangle

Silver: How many moles in?

1. 0.25 dm^3 of a 0.05 mol/dm^3 solution of sulfuric acid
2. 0.50 dm^3 of a 2 mol/dm^3 solution of sodium hydroxide?

Gold: Calculate . . .

1. The concentration in mole/dm^3 from 0.75 moles of copper sulfate in 500 cm^3 of water.
2. The number of moles of ethanoic acid in 25 cm^3 of a 1.5 mol/dm^3 solution

Bronze: What is the concentration in moles/dm^3 of:

1. 0.5 moles of hydrochloric acid in 1 dm^3 of water

$$c = \frac{\text{moles}}{\text{volume}} = \frac{0.5}{1} = 0.5\ \text{mol/dm3}$$

2. 1.5 moles of sodium carbonate in 0.5 dm^3 of water

$$c = \frac{\text{moles}}{\text{volume}} = \frac{1.5}{0.5} = 3\ \text{mol/dm3}$$

Silver: How many moles in?

1. 0.25 dm^3 of a 0.05 mol/dm^3 solution of sulfuric acid

$$\text{moles} = c \times \text{volume} = 0.05 \times 0.25 = 0.0125\ \text{moles}$$

2. 0.50 dm^3 of a 2 mol/dm^3 solution of sodium hydroxide?

$$\text{moles} = c \times \text{volume} = 2 \times 0.5 = 1\ \text{mole}$$

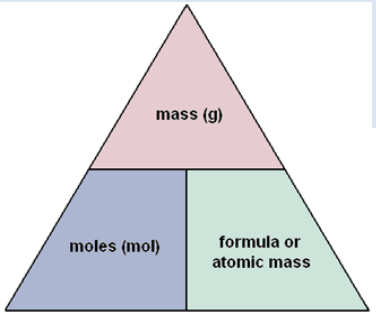
Gold: Calculate . . .

1. The concentration in mole/dm^3 from 0.75 moles of copper sulfate in 500 cm^3 of water.

$$c = \frac{\text{moles}}{\text{volume}} = \frac{0.75}{0.5} = 1.5\ \text{mol/dm3}$$

2. The number of moles of ethanoic acid in 25 cm^3 of a 1.5 mol/dm^3 solution $\text{moles} = c \times \text{volume} = 1.5 \times 0.025 = 0.0375\ \text{moles}$

6-Converting from mole/dm³ to g/dm³



To convert from mole/dm³ → g/dm³

Multiply the concentration by the RFM/RAM.

Tip: Ignore the dm³ and treat this as a moles to grams calculation

What is the concentration in g/dm³ of:

1. A 2 mol/dm³ solution of HCl (RAM H=1, Cl=35.5)

$$g/dm^3 = mol/dm^3 \times RFM = 2 \times 36.5 = 73 g/dm^3$$

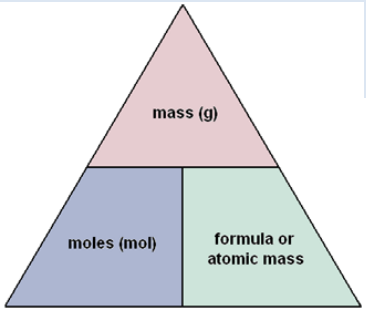
2. A 0.75 mol/dm³ solution of NaOH (RAM H=1, O=16, Na=23)

$$g/dm^3 = mol/dm^3 \times RFM = 0.75 \times 40 = 30 g/dm^3$$

3. A 0.05 mol/dm³ solution of NaCl (RAM Na=23, Cl=35.5)

$$g/dm^3 = mol/dm^3 \times RFM = 0.05 \times 58.5 = 2.9 g/dm^3$$

6-Converting from g/dm³ to mole/dm³



To convert the concentration from g/dm³ → mole/dm³ :

You divide by the RFM/RAM

Tip: Ignore the dm³ and treat this as a grams to moles calculation

What is the concentration in mole/dm³ of ?

1. A 2g/dm³ solution of magnesium chloride, $MgCl_2$ (RAM Mg=24, Cl=35.5)

$$\text{mole/dm}^3 = \frac{\text{grams/dm}^3}{\text{RFM}} = \frac{2}{95} = 0.021\ \text{mole/dm}^3$$

2. A 5g/dm³ solution of KOH (RAM K=39, O=16, H=1)

$$\text{mole/dm}^3 = \frac{\text{gram/dm}^3}{\text{RFM}} = \frac{5}{56} = 0.089\ \text{mole/dm}^3$$

7-Calculating the Concentration of an Unknown

$HCl + NaOH \rightarrow NaCl + H_2O$

Equation: $C_AV_A = C_BV_B$

C_A = concentration of acid, C_B = concentration of base/alkali

V_A = volume of acid added, V_B = volume of base/alkali added

Example: In a titration of hydrochloric acid and sodium hydroxide, 25 cm^3 of 0.50 M sodium hydroxide was added to a conical flask. From the burette, 23.25 cm^3 of hydrochloric acid was needed to neutralise the sodium hydroxide. What is the concentration of the hydrochloric acid?

$$C_A = \frac{C_BV_B}{V_A} = \frac{0.50 \times 25}{23.2} = 0.54M$$

7-Exam Questions

Q1. Sodium hydroxide solution is titrated with dilute hydrochloric acid. The results of the experiment are 25.0 cm^3 of sodium hydroxide solution reacted with 23.2 cm^3 of 0.100 mol dm^{-3} hydrochloric acid, HCl.
Calculate the concentration of this sodium hydroxide solution, NaOH, in mol dm^{-3}.

(3)

$NaOH + HCl \rightarrow NaCl + H_2O$

.....

concentration of sodium hydroxide solution = ...mol dm^{-3}

$$C_B = \frac{C_A V_A}{V_B} = \frac{0.100 \times 23.2}{25.0} = 0.0928\ M$$

Q2. In another experiment, a titration was carried out.
25.0 cm^3 of 1.50 mol dm^{-3} sodium hydroxide solution, NaOH, was titrated with hydrochloric acid.
The volume of the hydrochloric acid required to neutralise the sodium hydroxide solution was 30.0 cm^3.

Calculate the concentration of the hydrochloric acid, HCl, in mol dm^{-3}.

$HCl + NaOH \rightarrow NaCl + H_2O$

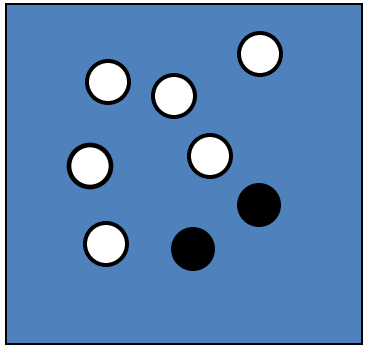
(3)

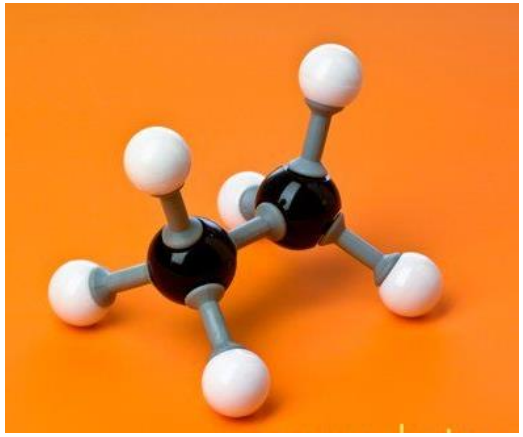
.....

$$C_A = \frac{C_B V_B}{V_A} = \frac{1.50 \times 25.0}{30.0} = 1.25\ M$$

.....

8-Molecular v. Empirical formula





This model shows a molecule of ethane. The black circles represent carbon (C) and the white circles are hydrogen (H).

Key Words:

The molecular formula is the actual number of atoms in the molecule.

The empirical formula is the simplest **whole** number formula of a compound.

Extension: What is the molecular formula of the molecule shown above? What is its empirical formula?

8-Finding the empirical formula

Example: What is the empirical formula of H_2O_2?

Answer: Divide everything by the smallest number in the formula – in this case 2. Dividing through by 2 gives HO.

TASK: Find the empirical formulas of the following:

1. C_6H_6 CH
2. $C_6H_{12}O_6$ CH_2O
3. C_4H_8 CH_2

8-Exam Question

The formula of a molecule of ethane is C_2H_6.

Give the empirical formula of ethane. (1)

To calculate the empirical formula, divide by the smallest number in the formula (2). This gives CH_3.

9-Calculating the molecular formula from the empirical formula

Example: The empirical formulae of a compound is CH_2O. The relative formula mass for the molecular formula is 180. What is the molecular formula?

Step 1: Calculate the relative formula mass for the empirical formula CH_2O:

RFM = 12 + (2x1) + 16= 30

Step 2: Divide the molecular RFM by the empirical RFM

180/30 = 6

Step 3: Multiply the empirical formula by that number

Molecular formula = $6xCH_2O = C_6H_{12}O_6$

9-Calculating the molecular formula from the empirical formula

Question: The empirical formulae of a compound is $AlCl_3$. The relative formula mass for the molecular formula is 267. What is the molecular formula?

Step 1: Calculate the relative formula mass of $AlCl_3$:

RFM = 27 + (3x35.5) = 133.5

Step 2: Divide the molecular RFM by the empirical RFM

267/133.5 = 2

Step 3: Multiply the empirical formula by that number

Molecular formula = 2x$AlCl_3$ = Al_2Cl_6

10-Calculating the Empirical Formula

Example: A compound of aluminium chloride contained 0.135g of aluminium and 0.533g of chlorine. What is its empirical formula?
(relative atomic mass (RAM) of Al=27, Cl=35.5)

Substance	**Aluminium Chloride**	
1. Elements	**Al**	**Cl**
2. $\frac{\text{Mass}}{\text{RAM}}$	$\frac{0.135\text{g}}{27} = 0.005$	$\frac{0.533}{35.5} = 0.015$
3. Divide by the smaller number	$\frac{0.005}{0.005} = 1$	$\frac{0.015}{0.005} = 3$
4. Ratio	**1:3**	
5. Formula	**$AlCl_3$**	

10-Exam Questions

Q1. In an experiment, 3.1 g of phosphorus reacted with 24 g of bromine to form phosphorus bromide.

Calculate the empirical formula of the phosphorus bromide.

You must show your working. (relative atomic masses: P = 31, Br = 80)

(3)

PBr_3

empirical formula .....

Q2. An oxide of lead was analysed.
0.414 g of lead was combined with 0.064 g of oxygen in this oxide.

Calculate the empirical formula of this lead oxide. (relative atomic masses: O = 16, Pb = 207)

(3)

empirical formula . . . . PbO_2 . . . . . .

Q3. A sample of calcium bromide contains 0.2 g calcium and 0.8 g bromine by mass.
Calculate the empirical formula of calcium bromide. (relative atomic masses: Ca = 40, Br = 80)

$CaBr_2$

Q4. 14.3 g of an oxide of copper contained 12.7 g of copper.
Calculate the empirical formula of this oxide.
Show your working.
(Relative atomic masses: Cu = 63.5, O = 16)

Cu_2O

answer = ...

10-Writing a Balanced Equation

Example: 3.2g of copper reacted with 0.8g of oxygen to form a copper oxide. (Atomic Mass Cu=64: O=16) Use this information to determine the balanced equation for this reaction.

1. Calculate the empirical formula of the product.

$$\text{Cu} = \frac{3.2}{64} = 0.05 \qquad \text{O} = \frac{0.8}{15} = 0.05 \qquad \text{CuO}$$

2. Write a symbol equation for the reaction:

$Cu + O_2 \rightarrow CuO$

3. Balance!

$2Cu + O_2 \rightarrow 2CuO$

10-Exam Question – writing an equation

When iron wool is heated in bromine vapour, it reacts to form iron bromide.

In an experiment, 5.60 g of iron reacted exactly with 24.0 g of bromine, Br_2.

[relative atomic masses: Fe = 56.0, Br = 80.0]

Determine, using this information, the balanced equation for the reaction between iron and bromine. You must show your working.

(4)

Question number	Answer	Additional guidance	Mark
	• calculates mol of Fe (1) • calculates mol of Br^2 (1) • determines simplest ratio/LHS of equation (1) • deduces formula of iron bromide produced/RHS of equation (1) OR • divides mass by relative atomic mass (1) • simplest ratio (1) • empirical formula (1) • deduces LHS to obtain balanced equation (1)	Example of calculation mol Fe = $\frac{5.6}{56} = 0.1$ mol Br_2 = $\frac{24}{(2\times80)}$ = 0.15 ratio Fe:Br_2 = 2 : 3/ 2Fe + 3Br_2 2$FeBr_3$/Fe_2Br_6 Fe : Br $\frac{5.6}{56}$: $\frac{24}{80}$ 0.1 : 0.3 1 : 3 $FeBr_3$ 2Fe + 3Br_2 → 2$FeBr_3$	(4)

This is the method you can use based on the prior slides

11-Calculating the Empirical Formula

Example: An oxide of magnesium, X, has the following percentage composition by mass: Mg, 60%; O 40%.

Calculate the empirical formula of X (relative atomic mass (RAM) of O=16, Mg=24)

Tip: Treat the % exactly how you treated the masses in calculation 10

Substance	**Magnesium Oxide**	
1. Elements	**Mg**	**O**
2. $\frac{\text{Mass}}{\text{RAM}}$	$\frac{60}{24} = 2.5$	$\frac{40}{16} = 2.5$
3. Divide by the smaller number	$\frac{2.5}{2.5} = 1$	$\frac{2.5}{2.5} = 1$
4. Ratio	**1:1**	
5. Formula	**MgO**	

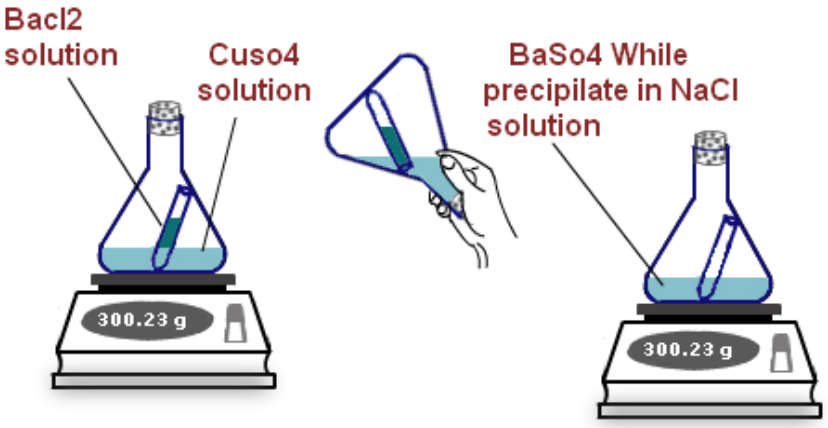
11-Calculating the Empirical Formula

1. An hydrocarbon, **Z**, has the following percentage composition by mass: C, 80%; H 20%. Calculate the empirical formula of **X** (RAM of H=1, C=12) CH_3

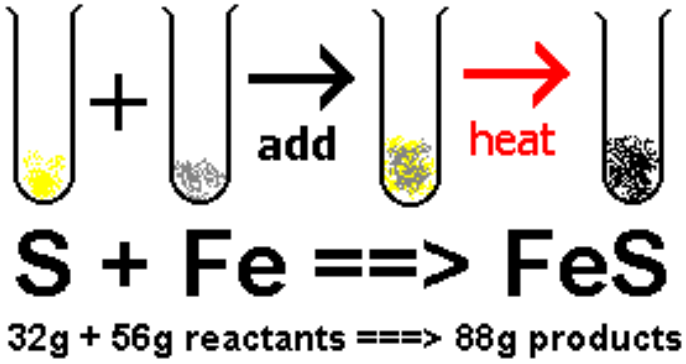
2. Silver nitrate has the following percentage composition by mass: Ag, 63.5%; N, 8.2%; O, 28.3%. Calculate the empirical formula. RAM of Ag=108, N=14, O=16)

$AgNO_3$

12-The Law of Conservation of Mass

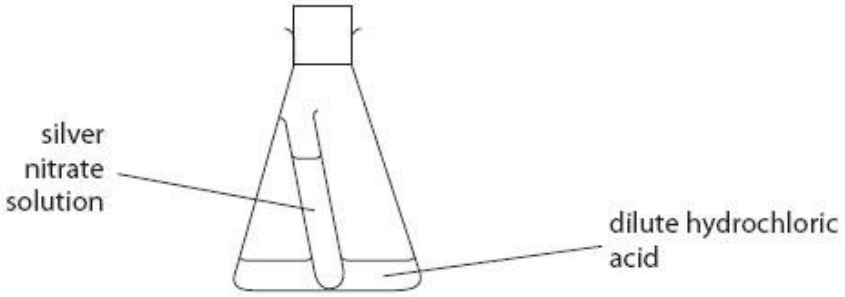


The total *mass* of *products* at the end of the reaction is equal to the total mass of the *reactants* at the beginning.



12-Exam Questions

Q1. Dilute hydrochloric acid reacts with silver nitrate solution to form silver chloride and nitric acid. This apparatus is used to investigate the mass of the reactants and the mass of products in this reaction.



The total mass of this apparatus was measured.
The flask was shaken to allow the silver nitrate solution and dilute hydrochloric acid to react.
After the reaction the total mass of the apparatus was measured again.
State how the total mass of the apparatus after the reaction will compare with the total mass of the apparatus before the reaction.

The mass will stay the same (1)

.....

Q2. When calcium carbonate is heated strongly it undergoes thermal decomposition.

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

2.50 g of calcium carbonate was heated strongly.
1.40 g of solid remained after heating.
Calculate the mass of carbon dioxide produced during this reaction.

The mass of the products = mass of the reactants. So 2.50 = 1.40 + mass of CO_2 (1)

.....

Mass of CO_2 = 2.50-1.40 = 1.10g

.....

12-Exam Questions

Q3. Propene can be made by cracking fractions obtained from crude oil.
This equation shows the cracking of decane to produce propene and butane.

$$C_{10}H_{22} \rightarrow 2C_3H_6 + C_4H_{10}$$

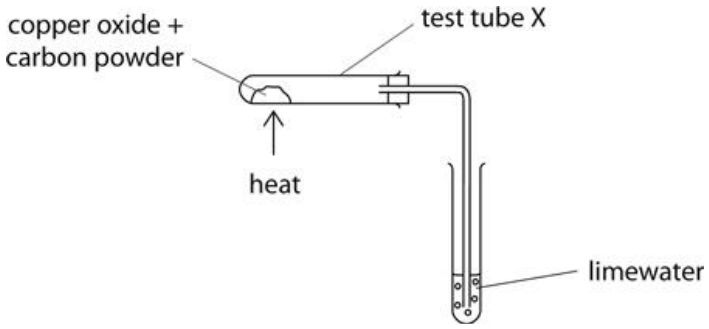
decane propene butane

Give the total mass of products formed if 17 g of decane is cracked in this way.

The mass products = mass of reactants = 17g (1)

.....

Q4. A mixture of copper oxide and carbon powder was heated. Carbon dioxide was produced. It was bubbled into limewater.



The word equation for the reaction is
copper oxide + carbon → copper + carbon dioxide

The mass of test tube X and its contents was measured before heating and after heating.
There was a change in mass.
Explain why the total mass of the test tube and contents changes during the reaction.

The decreased (got smaller) because the CO_2 left the test tube (2)

.....

.....

13-Reacting Mass Calculations

There are two methods for calculating reacting masses.

The first is the ratio method, which is easier to use but might make it harder to apply your knowledge to other questions.

The second method is based on using moles and is harder to use but will allow you to understand what is going on better.

Try these exam questions

13-Reacting Mass Calculations

Example: What mass of oxygen is needed to react with 12 of carbon to make carbon dioxide (CO_2)? (RAM for C=12, RFM for O_2=32)

The balanced equation is: $C + O_2 \rightarrow CO_2$

STEP 1

$$\frac{\text{Mass}_{\text{carbon}}}{\text{RAM}_{\text{carbon}}} = \frac{\text{Mass}_{\text{oxygen}}}{\text{RFM}_{\text{oxgyen}}}$$

STEP 2

$$\frac{12}{12} = \frac{\text{Mass}_{\text{oxygen}}}{32}$$

STEP 3

mass of oxygen = 32 g.

Q: What mass of carbon is needed to react with 16g of oxygen?

6g

13-Reacting Mass Calculations-Extension

Example: In a firework, potassium nitrate (KNO_3) decomposes to form potassium nitrite (KNO_2) and oxygen (O_2). The equation is: $2KNO_3 \rightarrow 2KNO_2 + O_2$

Calculate the mass of potassium nitrate that would be needed to make 1.6 g of oxygen (Relative formula masses: KNO_3 = 101; O_2 = 32)

STEP 1

$$2 \times \frac{\text{Mass}_{O2}}{\text{RFM}_{O2}} = 1 \times \frac{\text{Mass}_{KNO3}}{\text{RFM}_{KNO3}}$$

Note that the numbers are swapped. There is a 2 in front of the KNO_3 in the equation but in the ratio it goes in front of the oxygen.

STEP 2

$$2 \times \frac{1.6}{32} = 1 \times \frac{Mass_{KNO3}}{101}$$

Q: What mass of oxygen is made from 50.5 g of KNO_3? 16g

STEP 3

mass of KNO_3 = 10.1g

13-Reacting Mass Calculations—Using Moles

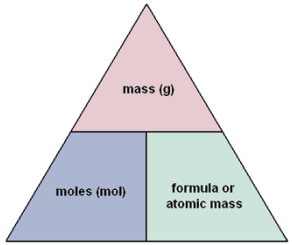
Example: Sodium chloride can be made from sodium hydroxide and hydrochloric acid according the this equation:

$NaOH + HCl \rightarrow NaCl + H_2O$

Calculate the mass of HCl needed to make 10 g of sodium chloride. RAM H = 1, Na = 23, O=16, Cl = 35.5

Step 1: Calculate the moles of NaCl. You will need to calculate the RFM as 23 + 35.5 = 58.5

$$\text{moles} = \frac{\text{mass}}{\text{RFM}} = \frac{10}{58.5} = 0.171$$



Step 2: The number of moles of HCl = NaCl because its a 1:1 reaction. So moles of HCl = 0.171

Step 3: Convert the moles of HCl back into grams. The RFM of HCl = 1 + 35.5 = 36.5

$$\text{g HCl} = \text{moles} \times \text{RFM} = 0.171 \times 36.5 = 6.3\,\text{g}$$

13-Reacting Mass Calculations—Using Moles

Example: In a firework, potassium nitrate (KNO_3) decomposes to form potassium nitrite (KNO_2) and oxygen (O_2). The equation is: $2KNO_3 \rightarrow 2KNO_2 + O_2$

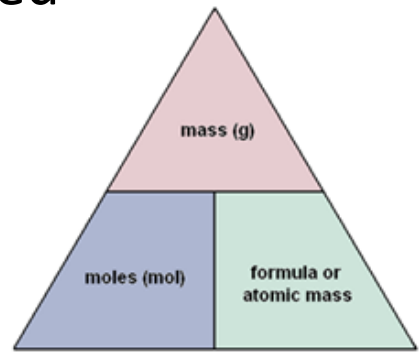
Calculate the mass of potassium nitrate that would be needed to make 1.6 g of oxygen

(Relative formula masses: $KNO_3 = 101$; $O_2 = 32$)

Step 1: Calculate the moles of O_2. $\text{moles} = \frac{\text{mass}}{\text{RFM}} = \frac{1.6}{32} = 0.05$

Step 2: Calculate the moles of KNO_3 using the balanced equation.

$$\text{moles } KNO_3 = 2 \text{ x moles } O_2 = 2 \times 0.05 = 0.1$$



Step 3: Convert the moles of KNO_3 back into grams.

$$\text{g } KNO_3 = \text{moles x RFM} = 0.1 \text{ x } 101 = 10.1 \text{ g}$$

13-Exam Questions

Sodium reacts with chlorine to form sodium chloride.

$$2Na + Cl_2 \rightarrow 2NaCl$$

Calculate the maximum mass of sodium chloride that could be formed by reacting 9.20 g of sodium with excess chlorine.
(relative atomic masses: Na = 23.0, Cl = 35.5)

(3)

.....

.....

In industry sodium carbonate is made from sodium chloride solution and calcium carbonate in the Solvay Process.
The overall equation for the Solvay Process is
$2NaCl + CaCO_3 \rightarrow Na_2CO_3 + CaC_2$
Calculate the maximum mass of sodium carbonate that could be formed by reacting 40 kg of calcium carbonate with an excess of sodium chloride solution.
(Relative formula masses: $CaCO_3 = 100$; $Na_2CO_3 = 106$)

(2)

13-Exam Questions

Question Number	Answer	Acceptable answers	Mark
(b)	**EITHER** 2x23 (1) g Na makes 2x58.5 (1) g NaCl 9.2 g Na makes $\frac{(2\times58.5)\times9.2}{46}$ g NaCl (1) (= 23.4 g) **OR** 23 g Na makes 58.5 (1) g NaCl 9.2 g Na makes $\frac{(58.5)\times9.2(1)}{23(1)}$ g NaCl (1) (= 23.4 g) mark consequentially eg 46 (1) g Na makes (2x23+35.5) (0) g NaCl 9.2 g Na makes $\frac{(2\times23+35.5)\times9.2}{46}$ (1) g NaCl (= 16.3 g)	23.4 g with no working (3) 23.4 g from any method (3) do not accept 23(.0) mol Na used = 9.2/23 (1) (= 0.4) mol NaCl = 0.4 (1) mass NaCl = 0.4 x 58.5 (1) (= 23.4 g) Ignore units throughout unless incorrect mark consequentially awarding 2 marks for 46.8 g,11.7 g and 16.3 g (see last example opposite).	**(3)**

13-Exam Questions

	Answer	Acceptable answers	Mark
	• 100 (kg) (calcium carbonate) → 106 (kg) (sodium carbonate) (1) • $\frac{106 \times 40}{100}$ (1) (=42.4)	OR alternative 106÷100 40000÷100 /40÷100 (moles approach) Only 42.4 with no working worth 2 marks 42400**g** worth 2 marks	**(2)**

13-Exam Questions

Q1. In an electrolysis, molten sodium fluoride is decomposed.

$$2NaF \rightarrow 2Na + F_2$$

(relative atomic masses: F = 19, Na = 23)
(relative formula mass NaF = 42)

Calculate the maximum mass of sodium that could be formed from 168 g of sodium fluoride.

(2)

mass = ... g

Q2. The thermal decomposition of copper carbonate forms copper oxide and carbon dioxide.

$$CuCO_3(s) \rightarrow CuO(s) + CO_2(g)$$

15.0 g of pure copper carbonate is decomposed completely. Calculate the mass of solid produced.(relative atomic masses: C = 12.0; O = 16.0; Cu = 63.5) Give your answer to two significant figures.

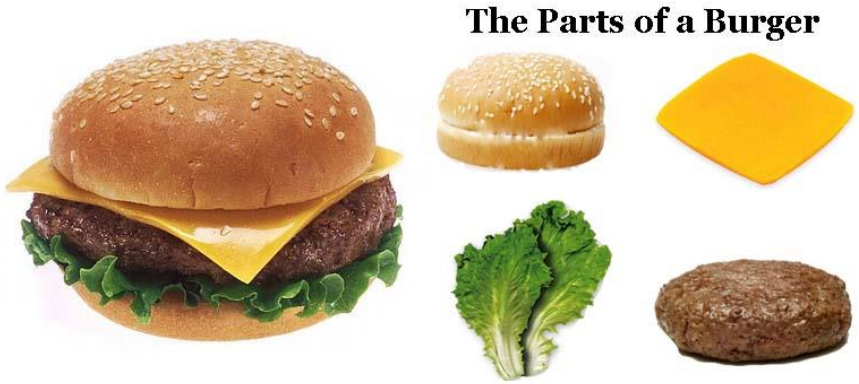
(2)

mass of solid = ... g

13-Exam Questions

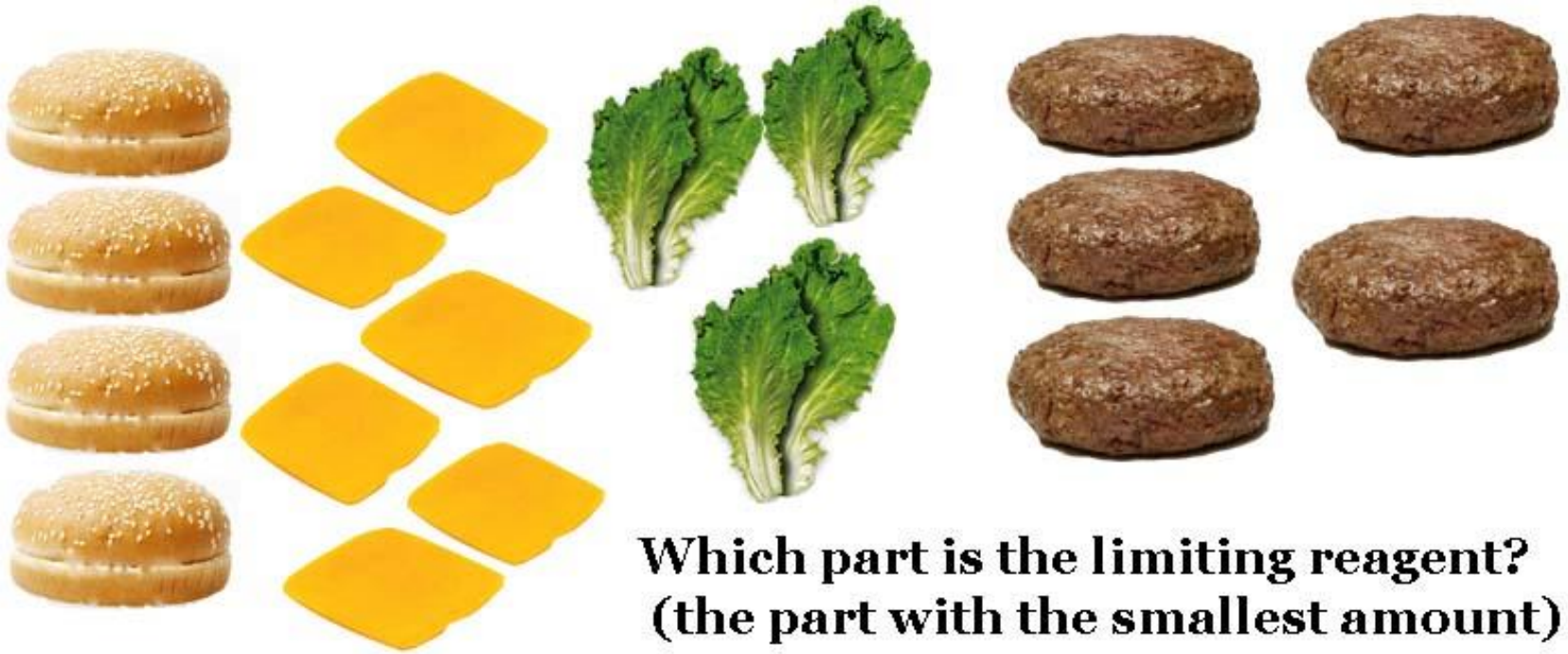
Question number	Answer	Mark
	• 84 g sodium fluoride → 46 g of sodium (1) • so 168 g sodium fluoride → 92 g of sodium (1) **or** • 168 ÷ 42 = 4 (mol NaF) (1) • 4 × 23 = 92 (g) (1)	

Answer
relative formula mass copper carbonate = 63.5 +12.0 +(3 × 16.0) = 123.5 relative formula mass copper oxide = 63.5 + 16.0 = 79.5 (1) mass copper oxide $= \frac{15.0 \times 79.5}{123.5}$ = 9.7 g to 2 s.f. (1) Answer must be to two significant figures OR moles of copper carbonate $= \frac{15.0}{123.5} = 0.12145$ (1) mass of copper oxide = moles $CuCO_3$ × 79.5 = 9.7 g to 2sf (1) Answer must be to two significant figures



- Only 3 burgers can be made.
- The limiting reagent is the lettuce leaves.

Question 1
How many burgers can be made?



Which part is the limiting reagent?
(the part with the smallest amount)

14-What is a limiting reagent?

The limiting reagent is the reactant that you have the least of. The amount of product you make depends of how much of the limiting reagent you have.

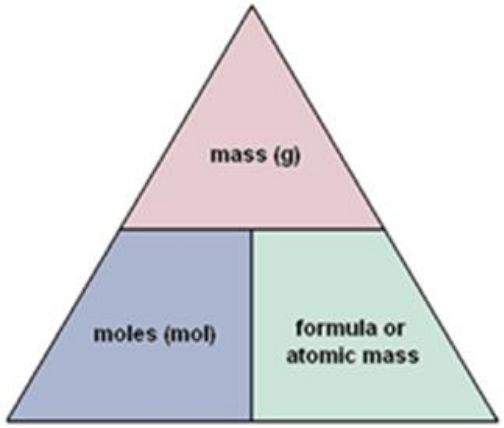
The reactant that you have the most of is said to be in excess.

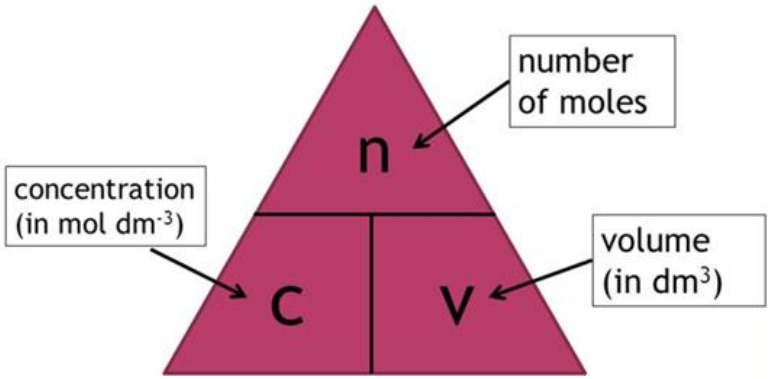
You could be asked to find the limiting reagent or the reagent in excess.

14-Finding the Limiting Reagent

To find the limiting reagent (or the reagent in excess) compare the moles of both reactants and see which is greater.

To find the moles, you will have to use one of the following triangles:





14-Finding the Limiting Reagent

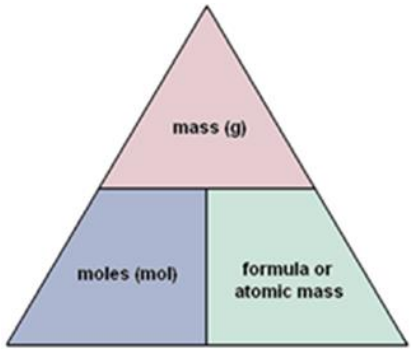
Example 1: Carbon reacts with oxygen to form carbon dioxide:

$C + O_2 \rightarrow CO_2$

If 1g of carbon reacts with 1g of oxygen, which is the limiting reagent? Which is in excess?

Calculate moles of carbon

$$\text{moles} = \frac{\text{mass}}{\text{RAM}} = \frac{1}{12} = 0.083$$



Use this triangle to find moles

Calculate moles of oxygen

$$\text{moles} = \frac{\text{mass}}{\text{RFM}} = \frac{1}{32} = 0.032$$

Answer: Oxygen is the limiting reagent and Carbon is in excess

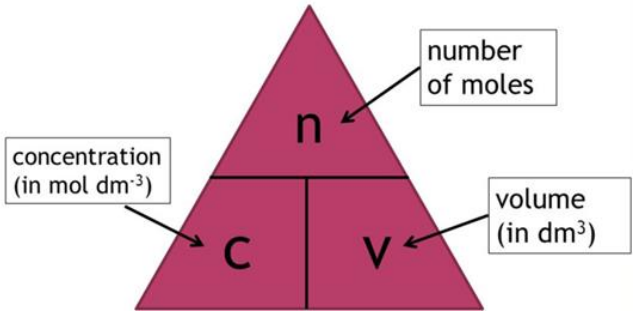
14-Finding the Limiting Reagent

Example 2: Hydrochloric acid and sodium hydroxide neutralise each other. $HCl + NaOH \rightarrow NaCl + H_2O$

If 1 dm^3 of 0.5 mol/dm^3 HCl reacts with 1dm^3 of 0.25 mol/dm^3 NaOH, which is the limiting reagent? Which is in excess?

Calculate moles of HCl

$$\text{moles} = c \times \text{volume} = 0.5 \times 1 = 0.5 \text{ moles}$$



Use this triangle to find moles

Calculate moles of NaOH

$$\text{moles} = c \times \text{volume} = 0.25 \times 1 = 0.25 \text{ moles}$$

Answer: NaOH is the limiting reagent and HCl is in excess

14-Finding the Limiting Reagent

1. What is the limiting reagent when 5g of Fe reacts with 5g of S to form iron sulphide?

Fe + S → FeS (RAM of Fe=56, S=32)

Answer: Iron is the limiting reagent and sulfur is in excess

2. What is the limiting reagent when 5 dm^3 of 0.25 mol/dm^3 of HCl reacts with 2 dm^3 of 0.5 mol/dm^3 NaOH?

$HCl + NaOH \rightarrow NaCl + H_2O$

Answer: NaOH is the limiting reagent and HCl is in excess

15-Calculating Percent Yield

$$\text{percent yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100\%$$

Questions:

1. What is the percentage yield of a reaction where the theoretical yield was 75 kg but the actual yield was 68 kg?

$$\text{percent yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100\% = \frac{68}{75} \times 100 = 91\%$$

2. During a practical a student made 30g of product, but the theoretical yield was 40g. What was the percentage yield?

$$\text{percent yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100\% = \frac{30}{40} \times 100 = 75\%$$

16-What is atom economy?

The atom economy of a chemical reaction is a measure of the amount of starting materials that become useful products.

$$\%\ \text{atom economy} = \frac{\text{total RFM of desired product}}{\text{total RFM mass of all products}} \times 100\%$$

16-How to calculate atom economy

Example: What is the atom economy for making hydrogen by reacting coal with steam?

$C(s) + 2H_2O(g) \rightarrow CO_2(g) + 2H_2(g)$

STEP 1: Calculate the total RFM of the desired product (H_2):

$C(s) + 2H_2O(g) \rightarrow CO_2(g) + 2H_2(g)$

2 × 2

=4

STEP 2: Calculate the total RFM mass of products

$C(s) + 2H_2O(g) \rightarrow CO_2(g) + 2H_2(g)$

44 + 2 × 2

=48

STEP 3: Put values into equation

% atom economy = $^{4}/_{48}$ × 100 = 8.3%

16-Calculating atom economy

Questions:

1. Calculate the atom economy for making hydrogen from methane:

$CH_4 + H_2O \rightarrow CO + 3H_2$ (RAM H=1, C=12, O=16)

STEP 1: Total RFM of desired product = 3 x 2 = 6
STEP 2: Total RFM of all products = 28 + 6 = 34
STEP 3: Atom economy = 6/34 x 100 = 18 %

2. What is the atom economy of this process to make ethanol?

$C_2H_4 + H_2O \rightarrow C_2H_5OH$ (RAM H=1, C=12, O=16)

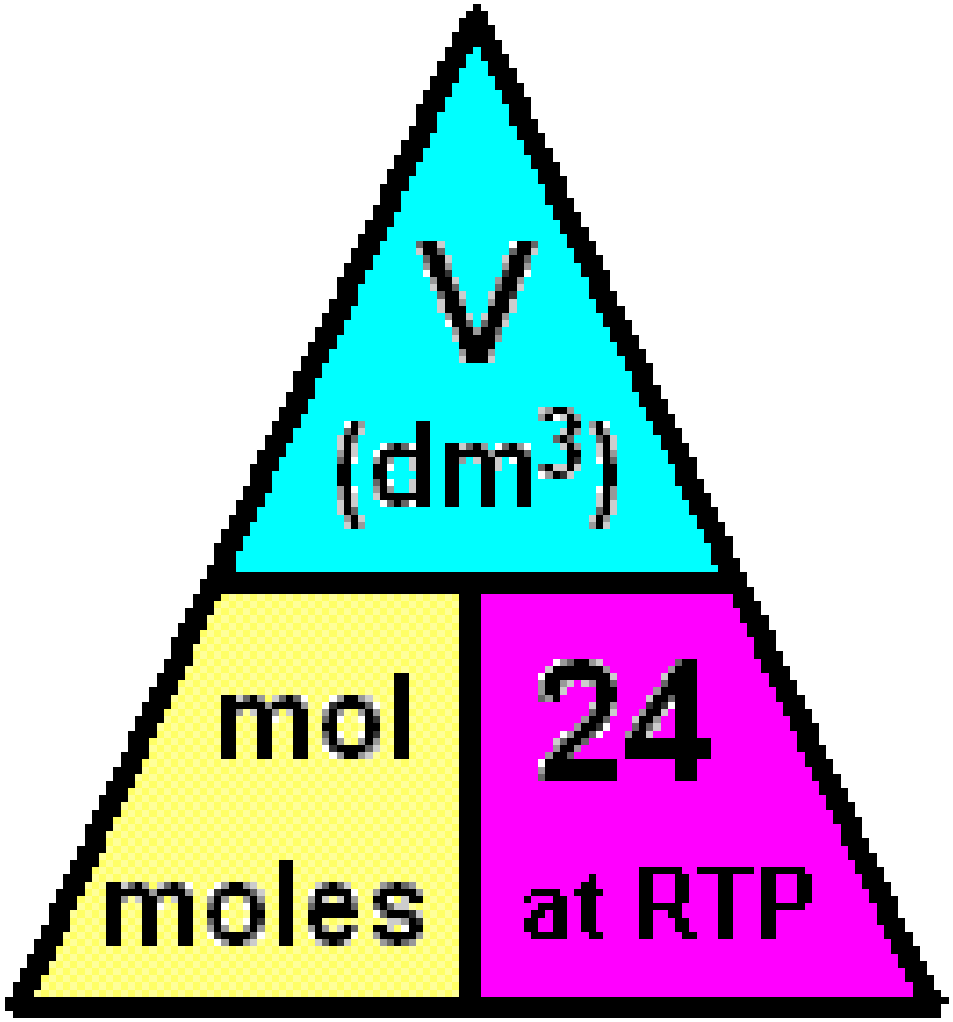
Because there is only one product the atom economy will be 100%

3. What is the atom economy of extracting iron from its ore?

$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$ (RAM Fe=56, C=12, O=16)

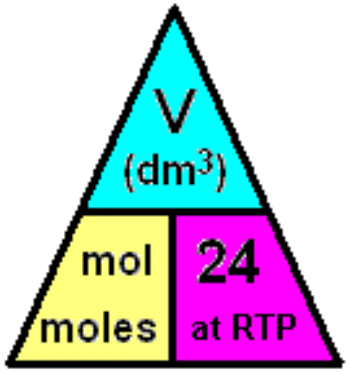
STEP 1: Total RFM of desired product = 2 x 56 = 112
STEP 2: Total RFM of all products = 112 + 3x44 = 244
STEP 3: Atom economy = 112/244 x 100 = 46 %

17-Using the molar volume



17-Calculating volume from moles

For all questions assumes it is room temperature and pressure (RTP), so the molar volume is 24 dm^3.



1. What is the volume of 1.5 moles of H_2 gas?

   $volume = moles \times 24 = 1.5 \times 24 = 36\ dm^3$

2. What is the volume of .25 moles of O_2 gas?

   $volume = moles \times 24 = 0.25 \times 24 = 6\ dm^3$

3. How many moles of CO_2 are there in 48 dm^3 of gas?

   $$moles = \frac{volume}{24} = \frac{48}{24} = 2 \text{ moles}$$

4. How many moles of Cl_2 are there in 2 dm^3 of gas?

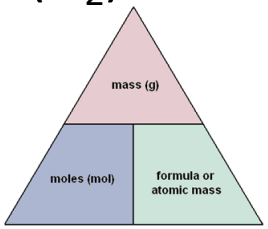
   $$moles = \frac{volume}{24} = \frac{2}{24} = 0.083 \text{ moles}$$

<u>Extension</u>:

1. How many grams of nitrogen are there in 10 dm^3 of nitrogen (N_2) gas? (RAM N = 14)

   STEP 1: $moles = \frac{volume}{24} = \frac{10}{24} = 0.417$ moles;

   STEP 2: mass= moles X RFM =11.7

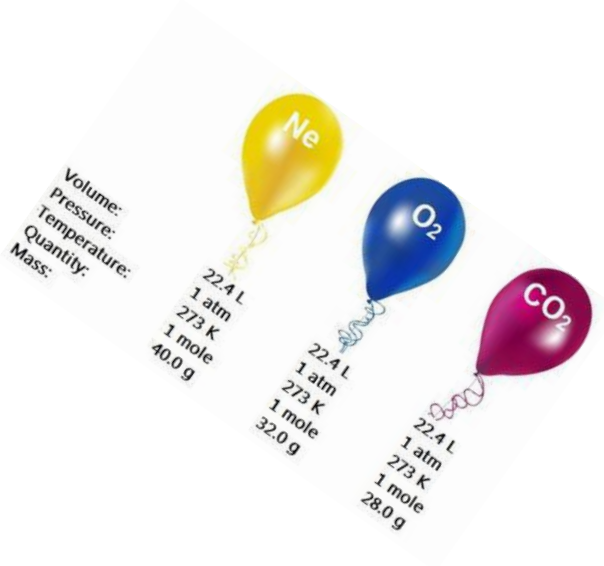


2. What is the volume of 1.2 g of Ne gas? (RAM Ne = 20)

   STEP 1: $moles = \frac{mass}{RAM} = \frac{1.2}{20} = 0.06$ STEP 2: $Volume = moles \times 24 = 1.44\ dm^3$

17-Gas Volumes and Reacting Masses

- Because the volume of gases is directly linked to the number of moles (and volume is the same for each gas), volumes can be used instead of moles in reacting mass calculations.



Example:

$Cl_2(g) + H_2(g) \rightarrow 2HCl\ (g)$

If there is 10 dm^3 of Cl_2, then there needs to be 10 dm^3 of H_2 to react completely with it. There would be 20 dm^3 of HCl made because the ratio is 2 to 1.

17-Exam Questions

Q1. Sulfur trioxide is produced by reacting sulfur dioxide with oxygen.

$$2SO_2 + O_2 \rightleftharpoons 2SO_3$$

What volume of oxygen, in cm^3, would react completely with 500 cm^3 sulfur dioxide?

(1)

- ☒ **A** 500 ÷ 2
- ☒ **B** 500
- ☒ **C** 500 × 2
- ☒ **D** 500 × 32

Q2. When nitrogen and hydrogen react to form ammonia, the reaction can reach a dynamic equilibrium.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

Calculate the minimum volume of hydrogen required to completely convert 1000 dm^3 of nitrogen into ammonia.

(1)

.....

..... 3000

volume of hydrogen = ... dm^3

Q3. Hydrogen reacts with oxygen to form water vapour.

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$$

If 200 cm^3 of hydrogen react completely with 100 cm^3 of oxygen, what is the maximum volume of water vapour formed, if all volumes are measured at the same temperature and pressure?

- ☒ **A** 100 cm^3
- ☒ **B** 200 cm^3
- ☒ **C** 300 cm^3
- ☒ **D** 400 cm^3

18-Isotopes & Calculating Relative Atomic Mass

How to Calculate Relative Atomic Mass.

Example. 80% of Boron atoms are the Boron-11 isotope. 20% of Boron atoms are the Boron-10 isotope. What is the relative atomic mass of Boron?

Step 1: (80 × 11) + (20 × 10) = 1080

Step 2: 1080 ÷ 100 = **10.8**

18-Isotopes & Calculating Relative Atomic Mass

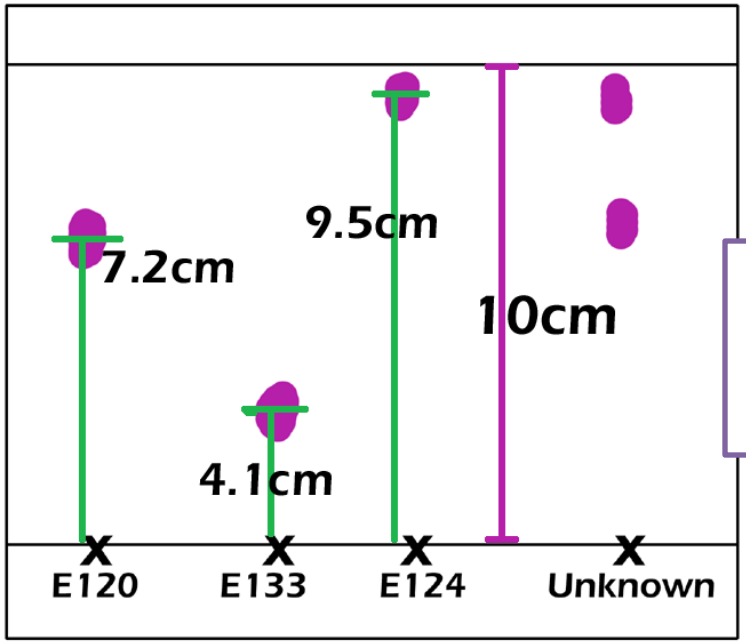
1. 75% of chlorine atoms are the ^{35}Cl isotope. 25% of chlorine atoms are the ^{37}Cl isotope. What is the relative atomic mass of chlorine? 35.5

2. Lithium has an atomic number of 3. A sample of lithium is 7.6% Lithium-6 and 92.4% Lithium-7. Calculate the relative atomic mass of lithium. 6.9

3. Neon has an atomic number of 10. A sample of neon is 90.5% Neon-20. The rest of the sample is Neon-22. Calculate the relative atomic mass of neon. 20.2

4. A sample of iron contains 6% Iron-54, 92% Iron-56 and 2% Iron-57. What is the relative atomic mass of iron in this sample? 55.9

19-Chromatography – Calculating the R_f Value



The answer is never greater than 1.

$$R_f = \frac{\text{distance moved by dot}}{\text{distance moved by solvent}}$$

Questions:

1. Which E numbers are in the unknown?
2. Which are pure?
3. Which are mixtures?
4. Which E number is most soluble in the liquid?

Substance	Distance moved by dot	Distance moved by liquid	Rf
E120			
E133			
E124			

19-Chromatography – Exam Question

Q3. The chromatography was carried out and the result is shown in Figure 12.

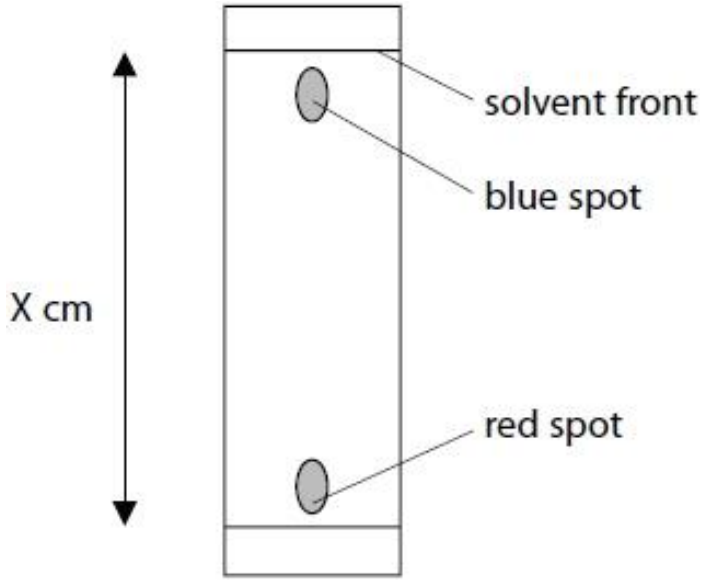


Figure 12

The blue spot had moved 14.5 cm and the solvent front had moved 15.3 cm.
Calculate the R_f value of the substance in the blue spot, giving your answer to 2 significant figures.

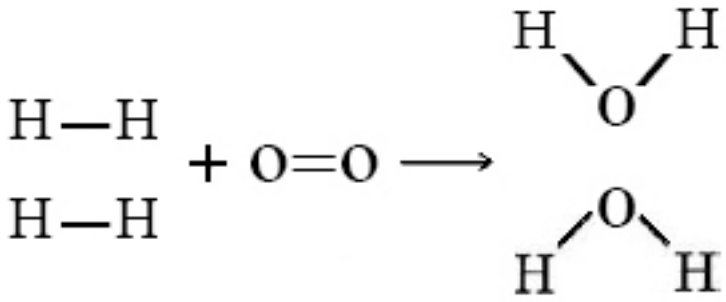
$$R_f \text{ value} = \frac{\text{distance travelled by a dye}}{\text{distance travelled by solvent front}}$$

(2)

$$R_f = \frac{14.5}{15.3} = 0.95$$

20-Bond Energy Calculations

Example: Calculate the energy change when water is formed from H_2 and O_2.



STEP 1 Bonds Broken

2 x (H-H) = 2 x 436 = 872

1 x (O=O) = 498

Total = 872 + 498 = 1370

Bond	Bond Energy
H-H	436
H-O	464
O=O	498

STEP 2 Bonds Made

4 x (O-H) = 4 x 464 = 1856

STEP 3

Energy change = bonds broken – bonds made

= 1370 – 1856 = -486

The negative sign means its exothermic.

20-Exam Question

Q5. The energies of some bonds are shown in Figure 13.

bond	energy of bond / kJ mol^{-1}
H—H	436
Cl—Cl	243

Hydrogen r

Calculate tl chlorine ga

1 mol of

(4)

STEP 1 Bonds Broken

1 x (H-H) = 436

1 x (Cl-Cl) = 243

Total = 436 + 243 = 679

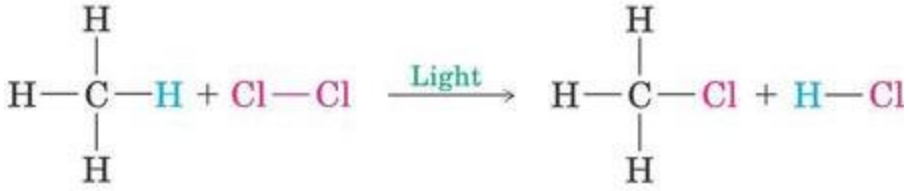
STEP 2 Bonds Made

2 x (H-Cl) = 2 x 432 = 864

STEP 3

Energy change = bonds broken – bonds made

= 679 – 864 = -185 exothermic



Methane **Chlorine** **Chloromethane**