Chestnut Grove Academy

Chemistry

3. Quantitative Chemistry

Revisiting Booklet

Name:

Positive   **R**esilient   **O**pen-minded   **U**nified   **D**etermined

Chemical measurements

What does the law of conservation state?

_____

_____

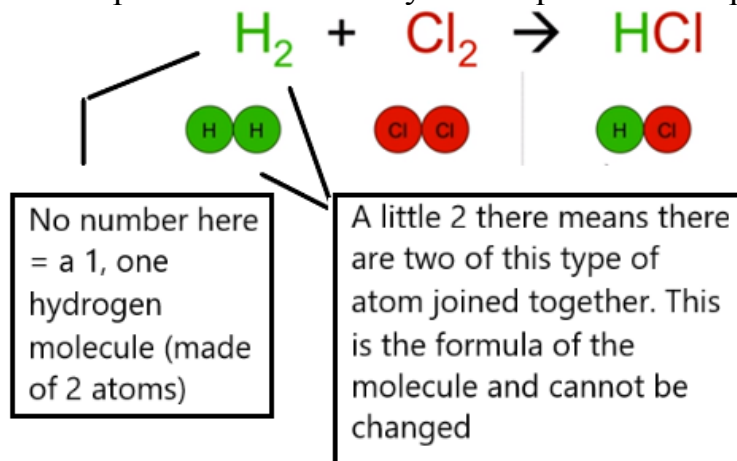Complete the missing masses:

Magnesium + Oxygen → Magnesium oxide

    5 g   + _____ →   5.6 g
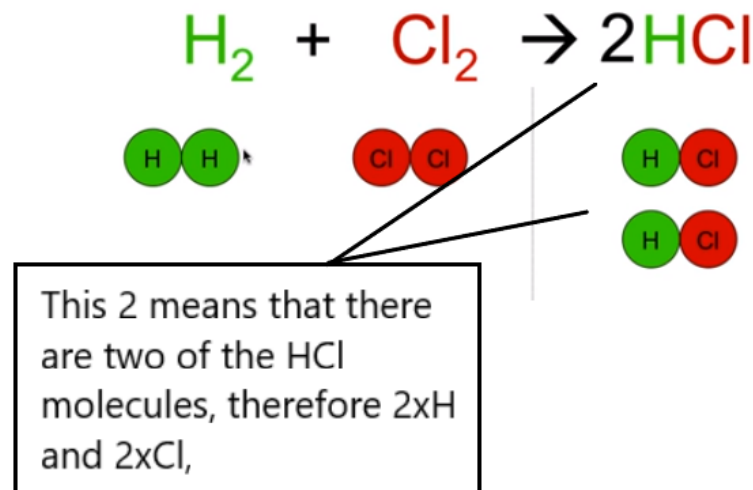
Iron oxide + carbon monoxide → iron + carbon dioxide

    150 g   + 20g   →   132g + _____ g

It is important to balance symbol equations to represent the law of conservation.

$$H_2 + Cl_2 \rightarrow HCl$$

No number here = a 1, one hydrogen molecule (made of 2 atoms)

A little 2 there means there are two of this type of atom joined together. This is the formula of the molecule and cannot be changed

Elements	Left	Right
H	2	1
Cl	2	1

You can only balance an equation by increasing the number of each type of molecule – adding a big number in front. For example:
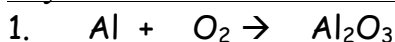
$$H_2 + Cl_2 \rightarrow 2HCl$$

This 2 means that there are two of the HCl molecules, therefore 2xH and 2xCl,

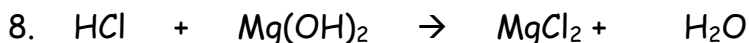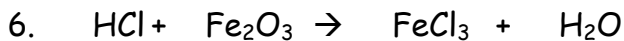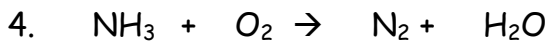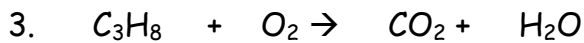| Elements	Left	Right
H	2	2
Cl	2	2

This equation is now balanced.

How many atoms are in the following:
$KMnO_4$

$Ca(OH)_2$

Try & balance the following equations:

1. $Al + O_2 \rightarrow Al_2O_3$

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

3. C_3H_8 + O_2 → CO_2 + H_2O

4. NH_3 + O_2 → N_2 + H_2O

5. N_2 + H_2 → NH_3

6. HCl + Fe_2O_3 → $FeCl_3$ + H_2O

7. Fe + O_2 → Fe_2O_3

8. HCl + $Mg(OH)_2$ → $MgCl_2$ + H_2O
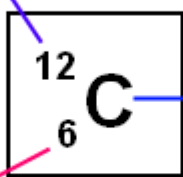
The relative atomic mass of an element is it's average mass compared to carbon, this mass takes into account the abundance of each isotope. The relative atomic mass of each atom can be found on the periodic table:

Carbon	
Relative atomic mass	
Atomic number	
Number of protons	
Number of neutrons	
Number of electrons	

What is an isotope?

_____

Relative atomic mass of an atom can be calculated using the following equation:

Relative
Atomic mass = (abundance x atomic)   +   (abundance x atomic)
of atom   __mass of isotope_____mass of isotope_____
                              total abundance

Calculate the following relative atomic masses:
   1.   bromine with 50% bromine-79 and 50% bromine-81

   2.   Magnesium with 79% magnesium-24, 10% magnesium-25 and 11% magnesium-26

What is relative formula mass (Mr)?

_____

Calculate the relative formula mass for the following molecules:
- NaOH
- $CuSO_4$
- NH_3
- $Ba(OH)_2$

In a balanced chemical equation, the sum of the relative formula masses of the reactants in the quantities shown _____ the sum of the relative formula masses of the products in the quantities shown. Why would this reaction appear to involve a mass change?

$$Mg + 2HCl \rightarrow MgCl_2 + H_2$$

_____
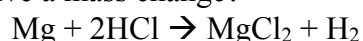
Percentage Composition

What is the percentage of:
1. N in NH_3

2. S in $FeSO_4$

3. S in H_2SO_4

4. O in $Al(OH)_3$
5. N in $(NH_4)_2SO_4$

Uncertainty

Whenever a measurement is made there is always some uncertainty about the result obtained. We can estimate uncertainty in two ways:
1. Considering the resolution of measuring instruments
2. From the range of a set of repeat measurements

Resolution of instrument is plus or minus half of the smallest division that it measures to:

Measurement cm^3	Uncertainty cm^3	Minimum Volume cm^3	Maximum Volume cm^3
80.0	±0.05		
75.5	±0.10		
60	±0.20		
120	±0.25		

Resolution:
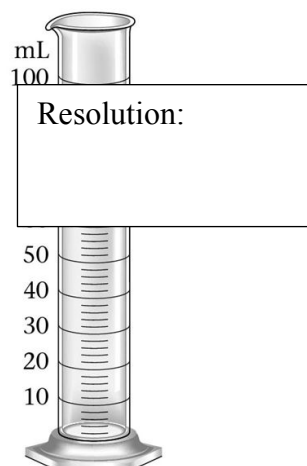
Range of data:

From data we could either calculate the uncertainty of a mean result or draw error/range bars on a graph – the larger the error/range bar to more uncertainty

Uncertainty of a mean result = range/2

Velocity versus Time

Range bar - a bar from the lowest to highest result
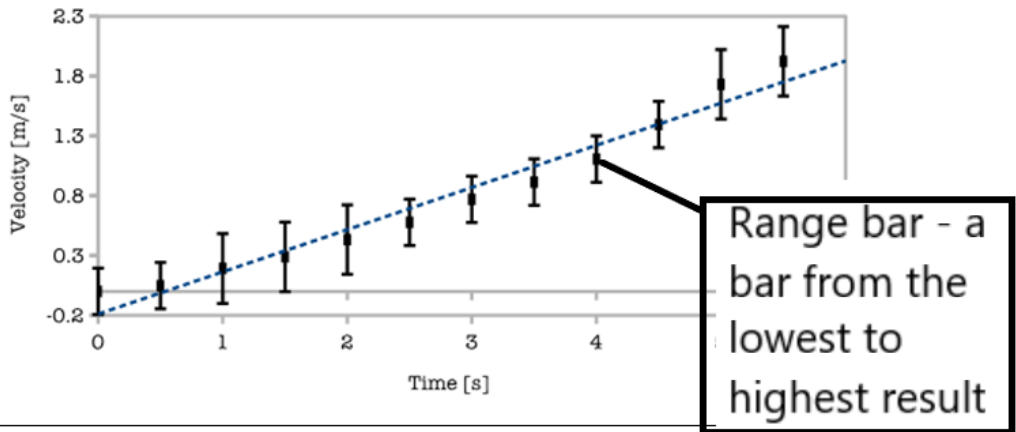
Calculate the missing mean for drop height 40cm.
Give the uncertainty in your answer.

Drop height in cm	Roll height in cm			
	Test 1	Test 2	Test 3	Mean
20	15	14	14	14
40	29	33	32	
60	47	19	46	46
80	65	61	63	63

_____

_____

Mean ……………….. cm   Uncertainty ………………. Cm

Practise drawing the error/range bars below:

Drawing Error Bars

Height of ramp (cm)	Time (s) 1	Time (s) 2	Time (s) 3	Average Time (s)
2	64	63	65	64
6	30	29	40	33
8	28	23	27	26
10	15	10	14	13
12	5	3	4	4

Graph: Time (s) on y-axis (0 to 70), Height of ramp (cm) on x-axis (0 to 12).
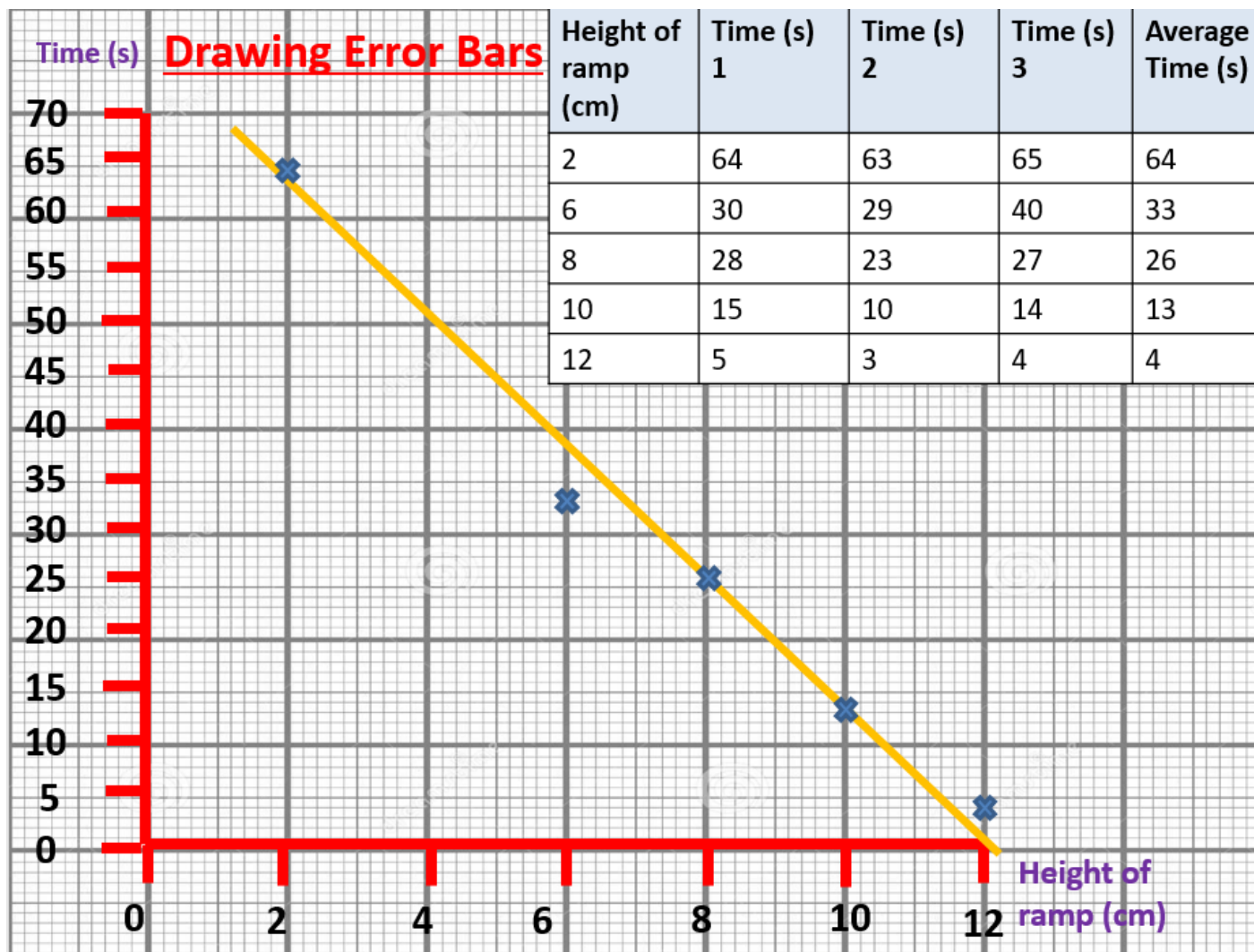
Higher tier only
Use of amount of substance
What is a mole?

_____

What is Avogadro's constant?
In chemistry we use the term mole – give a different example in another industry

_____

What is the unit for mole?

_____

Triangle: mass (g) on top; amount (mol) and relative formula mass (g mol^{-1}) on bottom.
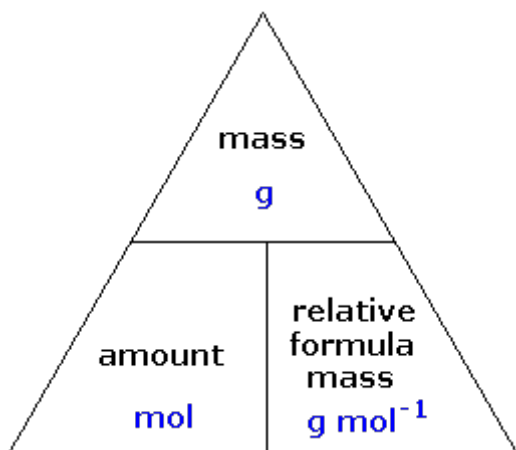
The mass of one mole of substance in grams is numerically equal to its relative formula mass. E.g. the mass of one mole of water is 18.

1. *How many atoms are in one mole of carbon?*

   _____

2. *How many molecules are in one mole of water?*

   _____

Calculate the number of moles of 4g of MgO.	*Calculate the mass of 2.5 moles of N_2.*
Calculate the number of moles of 0.25g of H_3PO_4.	*Calculate the mass of 0.8 moles of $CuSO_4$.*

What is the molar mass?

_____

Reacting Masses
You can use a balance symbol equation to calculate the mass of a reactant or product:

If 28 g of iron reacts with copper sulphate solution, what mass of copper will be made?

Fe + CuSO$_4$ → Cu + FeSO$_4$

	Fe	Cu
mass	28g	0.5x63.5 = **31.75g**
M$_r$	56	63.5
moles	28/56 = 0.5	0.5

1. *How much calcium oxide (CaO) is when 100g of calcium carbonate (CaCO$_3$) is heated?*
   CaCO$_3$ → CaO + CO$_2$
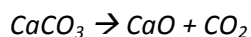
2. *What mass of lime (CaO) is created by fully decomposing 200g of calcium carbonate (CaCO$_3$)?*
   CaCO$_3$ → CaO + CO$_2$
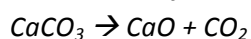
3. *Sulphur burns in air to form sulphur dioxide. What mass of sulphur dioxide is created on burning 8g of sulphur?*

$S + O_2 \rightarrow SO_2$
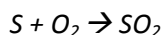
4. What mass of lime (CaO) is created by fully decomposing 20g of calcium carbonate ($CaCO_3$)?
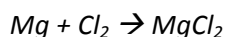
$CaCO_3 \rightarrow CaO + CO_2$
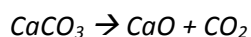
5. When magnesium is heated in chlorine gas it reacts to form magnesium chloride, $MgCl_2$. What mass of magnesium chloride will be formed from 72g of magnesium?

$Mg + Cl_2 \rightarrow MgCl_2$

Using moles to balance equations

Given masses for the following equation; 150g ethane, 560g of oxygen, 440g of carbon dioxide and 270g of water: Ethane + oxygen → carbon dioxide + water
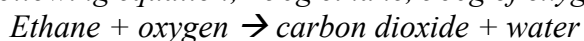
1) Work out moles for each species

	C_2H_6	O_2	CO_2	H_2O
Mass	150	560	440	270
Mr	30	32	44	18
Moles	5	17.5	10	15
/smallest moles	1	3.5	2	3

2) Use this to get the mole ratio

2:7:4:6

3) Use mole ratio to write the balanced symbol equation

$2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$

Try the following for yourself:

1) Write the balanced symbol equation for 488g of Sb reacting with 425g of Cl_2 to make 914g of $SbCl_3$

2) Write the balanced symbol equation for the 24g of Magnesium (Mg) reacting with 16g of Oxygen (O_2) to produce 40g of Magnesium oxide MgO

What is a limiting reactant?

_____

When calculating masses of reactants & products, you may need to first find out which moles are limiting and use these rather than any in excess.

1) In the manufacture of the fertiliser ammonium sulphate, what is the maximum mass of ammonium sulphate that can be obtained from 2.00 kg of sulphuric acid and 1.00 kg of ammonia?
$H_2SO_4 + 2 NH_3 \rightarrow (NH_4)2SO_4$
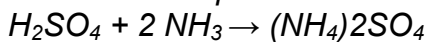
2) In the Solvay process, ammonia is recovered by the reaction shown. What is the maximum mass of ammonia that can be recovered from 2.00 tonnes of ammonium chloride and 0.500 tonnes of calcium oxide?
$2 NH_4Cl + CaO \rightarrow CaCl_2 + H_2O + 2 NH_3$

What is meant by the term concentration?

_____

_____

Give three examples of solutions that need to be diluted and the reason why:

1. _____
2. _____
3. _____

What is the equation for calculating concentration from mass?

Volume is often recorded in dm^3
- 1ml = 1 cm^3
- 1l = 1 dm^3
- 1dm^3 = 1000cm^3

What is 750cm^3 in dm^3?

1. 0.5 grams of sodium chloride is dissolved to make 0.05 dm^3 of solution in g/dm^3

2. 0.5 grams of sodium chloride is dissolved to make 0.05 cm^3 of solution in g/dm^3.

3. 6.7 x 10^{-2} grams of $Pb(C_2H_3O_2)_4$ are dissolved to make 3.5 dm^3 of solution in g/dm^3.

Higher tier
If the volume is kept the same and more mass is added, the concentration _____ _____
If water evaporated from a solution of copper sulphate, the concentration _____

Triple Higher tier Only

What is the equation for calculating concentration in mol/dm^3?

1. 0.5 moles of sodium chloride is dissolved to make 0.05 dm^3 of solution in mol/dm^3.

2. 0.5 grams of sodium chloride is dissolved to make 0.05 dm^3 of solution in mol/dm^3.

3. 734 grams of lithium sulfate **Li$_2$SO$_4$** are dissolved to make 2500 cm^3 of solution in mol/dm^3

You can use to concentration of one reactant to calculate the concentration of the other reactant – typically does by titration

1. Work out the moles of the known substance (using concentration= moles/volume)

2. Working out the moles of the unknown substance using the molar ratio in the reaction equation

3. Work out the concentration of the unknown substance (using concentration = moles/volumes)
Example: 20 cm^3 of 0.1mol/dm^3 NaOH neutralizes 25 cm^3 of HCl of unknown concentration

	Known reactant e.g. NaOH	**Unknown reactant e.g. HCl**
Concentration	0.1	0.0025 / 0.025 = 0.1
Volume	25/1000 = 0.025	25/1000 = 0.025
moles	0.1 x 0.025 = 0.0025	0.0025 (as 1:1 in equation)

1. In a titration, 20 cm^3 of 2.0 mol dm^{-3} HCl reacted with 25 cm^3 of NaOH. What was the concentration of the sodium hydroxide?

2. In a titration, 20 cm^3 of 0.2 mol dm^{-3} HCl reacted with 50 cm^3 of NaOH. What was the concentration of the sodium hydroxide?

Titrations

Draw a labelled diagram to show how to carry out a titration.

What is the difference between a single and mixed indicator? Give an example each.

_____

_____

Indicator	Colour in acid	Colour in alkali
Universal		
Litmus		
Phenolphthalein		

Why should a titration use a single indicator instead of a mixed indicator?

_____

Titration number	1	2	3	4
Final burette reading in cm³	26.5	49.2	26.4	40.3
Initial burette reading in cm³	0.0	24.1	1.2	15.0
Titre (volume of acid added) in cm³	26.5	25.1	25.2	25.3

Why is the mean for the titre calculated to be $25.2cm^3$?

_____

How do you convert from mol/dm^3 to g/dm^3 & visa versa?

Gas Volumes

Draw a labelled diagram that could be used to collect gas made in an experiment.

Volume of oxygen (cm³)
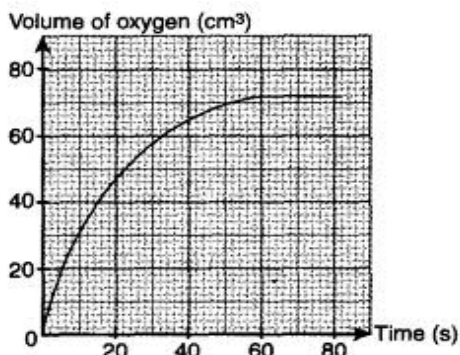
1. What is the maximum amount of gas collected?

_____   ____

2. When does the reaction stop?

_____   _____

3. Why does the reaction stop?

_____

_____

_____

4. When was the reaction the fastest? How do you know?

_____

_____

What is the equation to work out moles of a gas from volume, at room temperature & pressure?

1. What is the volume of half a mole of nitrogen?   _____

2. What is the volume of 3 moles of hydrogen?   _____

3. 6dm^3 of oxygen is how many moles?   _____

Yield & atom economy

Percentage yield compares the amount of product made (actual yield) to the amount expected (theoretical yield).

100% percentage yield means………………………………………………….

0% percentage yield means………………………………………………….

What are the possible ways of reducing percentage yield?

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

1. What is the percent yield for a reaction if you predicted the formation of 21g of C_6H_{12} and actually recovered only 3.8g?

2. Iron is extracted from iron oxide in the Blast Furnace:

$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$ (RFM: Fe_2O_3=160, Fe=56)

i) Calculate the maximum theoretical mass of iron that can be made from 100g of iron oxide.

ii) In the reaction, only 65 g of iron was made. Calculate the % yield.

Why do industrial processes want as high a percentage yield as possible?

1..

2..

3..

4..

Atom Economy

Atom economy is a way of measuring the amount of atoms that are wasted when manufacturing a chemical:

100% atom economy means ……………………………………………………………………..

The higher the atom economy the …………………………….. the process.

$$\text{Atom economy} = \frac{M_r \text{ of all desired products}}{\text{sum of } M_r \text{ of all products}} \times 100$$

Q1 Show that this reaction has a 6.7% atom economy: $C + H_2O \rightarrow CO + H_2$

Why do industrial processes want as high a atom economy as possible?

1……………………………………………………………………………………………………….
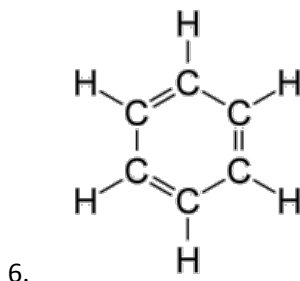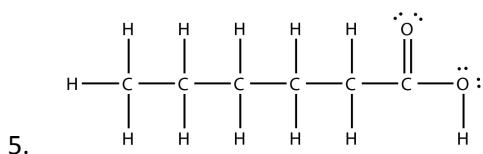
2……………………………………………………………………………………………………….

Empirical Formula
What is an empirical formula?

_____

_____

What is the empirical formula for:
1. $C_6H_{12}O_6$
2. H_2O_2
3. P_4O_{10}
4. $C_{12}H_{24}$

5.

6.

Example of how to calculate empirical formula:
What is the empirical formula of a compound that contains 60g of Carbon, 13g of hydrogen and 27g of oxygen?

	C	H	O

Mass or percentage	60	13	27
A_r	12	1	16
Moles	60/12 = 5	13/1 = 13	27/16 = 1.6875
÷ by smallest	5/1.6.. = 2.96	13/1.6.. = 7.7	1.6../1.6.. = 1
Round	**3**	**8**	**1**
Formula	**C_3H_8O**		

Note: get it to a whole number by multiplying NOT rounding. E.g. 0.5 x2, 0.25 x 4

1. What is the empirical formula of a compound that contains 3.31g of carbon and 0.69g of hydrogen?

2. What is the empirical formula of a compound that contains 43.4% sodium, 11.3% carbon and 45.3% oxygen?