Working out empirical formulae

The **empirical formula** of a substance is the simplest whole number ratio of its atoms. For example:

- the molecular formula of ethane is C_2H_6
- its empirical formula is CH_3 (because you can divide 2 and 6 by 2 to get smaller whole numbers).

Worked example

A compound consists of 27.3% carbon and 72.7% oxygen by mass. Deduce its empirical formula.

What you do		What you get	
Step 1	Make a column for each element	C	O
Step 2	Write their masses in g under each element (assume you have 100 g if you are given percentages)	27.3	72.7
Step 3	Write the A_r values under each mass	12	16
Step 4	Divide the mass of each element by its A_r	$\frac{27.3}{12} = 2.275$	$\frac{72.7}{16} = 4.55$
Step 5	Divide each answer found at Step 4 by the smallest answer	$\frac{2.275}{2.275} = 1$	$\frac{4.55}{2.275} = 2$
Step 6	Check that you have whole numbers, then write out the empirical formula (it is easy to forget to do this!)	Empirical formula is CO_2	

Questions

1. Find the empirical formulae of the compounds with these percentage compositions by mass:
   (a) 60% magnesium, 40% oxygen
   (b) 36% beryllium, 64% oxygen
   (c) 80% carbon, 20% hydrogen

2. Find the empirical formulae of the following compounds:
   (a) A compound containing 4 g of hydrogen and 32 g of oxygen
   (b) A compound containing 24 g of calcium and 5.6 g of nitrogen
   (c) A compound containing 0.31 g of phosphorus and 1.07 g of chlorine

3. Find the empirical formulae of the compounds formed when:
   (a) 4.02 g of mercury forms 4.66 g of a mercury sulfide
   (b) 0.62 g of phosphorus forms 4.17 g of a phosphorus chloride
   (c) 3.92 g of iron forms 8.89 g of an iron chloride

Use these relative atomic masses.

Element	H	Be	C	N	O	Mg	P	S	Cl	Ca	Fe	Hg
A_r	1	9	12	14	16	24	31	32	35.5	40	56	201

Working out empirical formulae – ANSWERS

1. (a) 60% magnesium, 40% oxygen

Mg $\frac{60}{24} = 2.5$	O $\frac{40}{16} = 2.5$	Divide each by 2.5	MgO

(b) 36% beryllium, 64% oxygen

Be $\frac{36}{9} = 4$	O $\frac{64}{16} = 4$	Divide each by 4	BeO

(c) 80% carbon, 20% hydrogen

C $\frac{80}{12} = 6.66$	H $\frac{20}{1} = 20$	Divide each by 6.66	CH_3

2. (a) 4 g hydrogen, 32 g oxygen

H $\frac{4}{1} = 4$	O $\frac{32}{16} = 2$	Divide each by 2	H_2O

(b) 24 g calcium, 5.6 g nitrogen

Ca $\frac{24}{40} = 0.6$	N $\frac{5.6}{14} = 0.4$	Divide each by 0.4, then multiply by 2 to remove the half	Ca_3O_2

(c) A compound containing 0.31 g of phosphorus and 1.07 g of chlorine

P $\frac{0.31}{31} = 0.01$	Cl $\frac{1.07}{35.5} = 0.03$	Divide each by 0.01	PCl_3

3. (a) 4.02 g of mercury forms 4.66 g of a mercury sulfide.
This means there must be (4.66 – 4.02) = 0.64 g of sulfur in the compound.

Hg $\frac{4.02}{201} = 0.02$	S $\frac{0.64}{32} = 0.02$	Divide each by 0.02	HgO

(b) 0.62 g of phosphorus forms 4.17 g of a phosphorus chloride.
This means there must be (4.17 – 0.62) = 3.55 g of chlorine in the compound.

P $\frac{0.62}{31} = 0.02$	Cl $\frac{3.55}{35.5} = 0.1$	Divide each by 0.02	PCl_5

(c) 3.92 g of iron forms 8.89 g of an iron chloride.
This means there must be (8.89 – 3.92) = 4.97 g of chlorine in the compound.

Fe $\frac{3.92}{56} = 0.07$	Cl $\frac{4.97}{35.5} = 0.14$	Divide each by 0.07	$FeCl_2$