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AMOUNT OF SUBSTANCE

THE MOLE

pair	2
dozen	12
score	20
gross	144
mole	602204500000000000000000 6.02×10^{23}

MOLES

1 mole of H_2O molecules has mass 18.0 g
(M_r of H_2O = 18.0)

1 mole of C atoms has mass 12.0 g
(M_r of C = 12.0)

THIS IS NOT A COINCIDENCE!

Chemists have worked how many particles are in the M_r in grams of any substance – this number is the mole (6.02×10^{23})

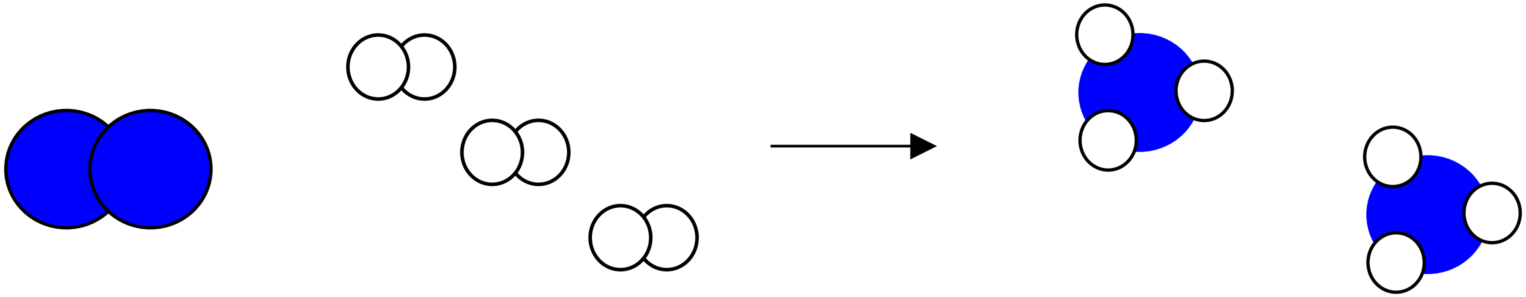
MOLES

$$\text{Mass (g)} = M_r \times \text{moles}$$

Remember "Mr Moles"

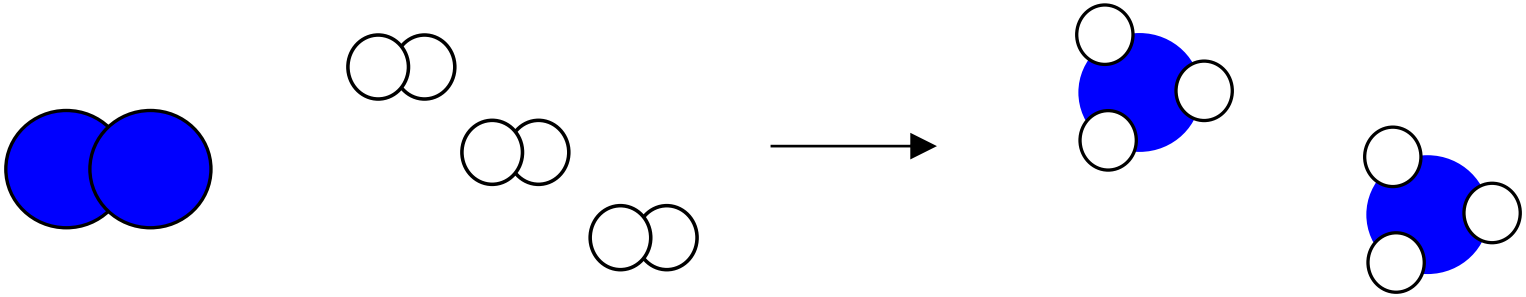
Mass (g)

M_r x moles



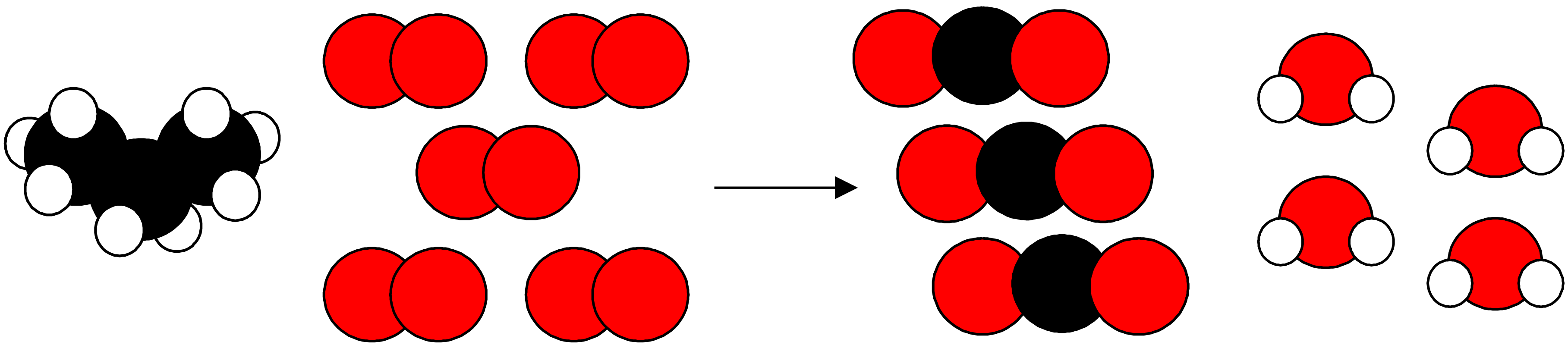
$$N_2 + 3\,H_2 \rightarrow 2\,NH_3$$

1 molecule	3 molecules	2 molecules
12	36	24
1 dozen	3 dozen	2 dozen
6×10^{23}	18×10^{23}	12×10^{23}
600000000000000000000000	1800000000000000000000000	1200000000000000000000000
1 mole	3 moles	2 moles



$$N_2 + 3\,H_2 \longrightarrow 2\,NH_3$$

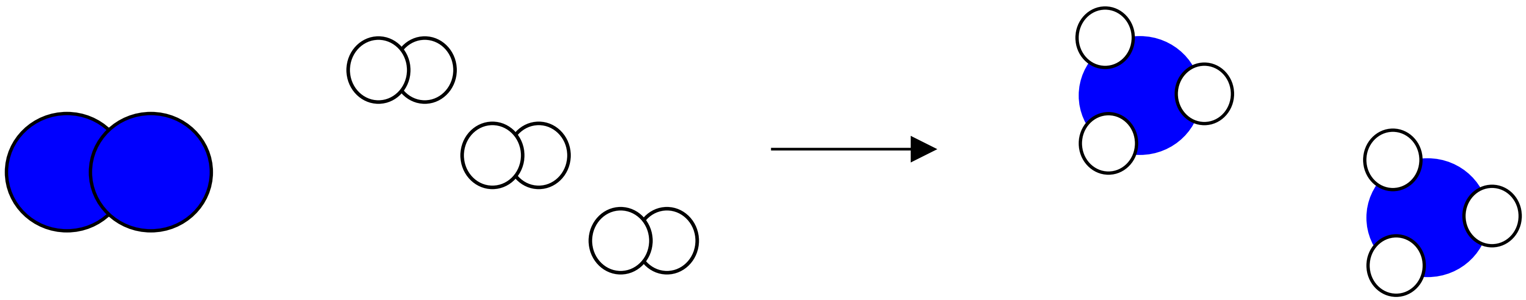
1 mole	3 moles	2 moles
10 moles	30 moles	20 moles
2 moles	6 moles	4 moles
0.5 moles	1.5 moles	1.0 moles
4 moles	12 moles	8 moles



$$C_3H_8 + 5\,O_2 \longrightarrow 3\,CO_2 + 4\,H_2O$$

1 molecule	5 molecules	3 molecules	4 molecules
10 moles	50 moles	30 moles	40 moles
2 moles	10 moles	6 moles	8 moles
0.5 moles	2.5 moles	1.5 moles	2 moles
0.03 moles	0.15 moles	0.09 moles	0.12 moles

LIMITING REAGENTS



$$N_2 + 3\,H_2 \longrightarrow 2\,NH_3$$

START 3 moles 3 moles

3 moles of N_2 needs 9 moles of H_2 for it all to react

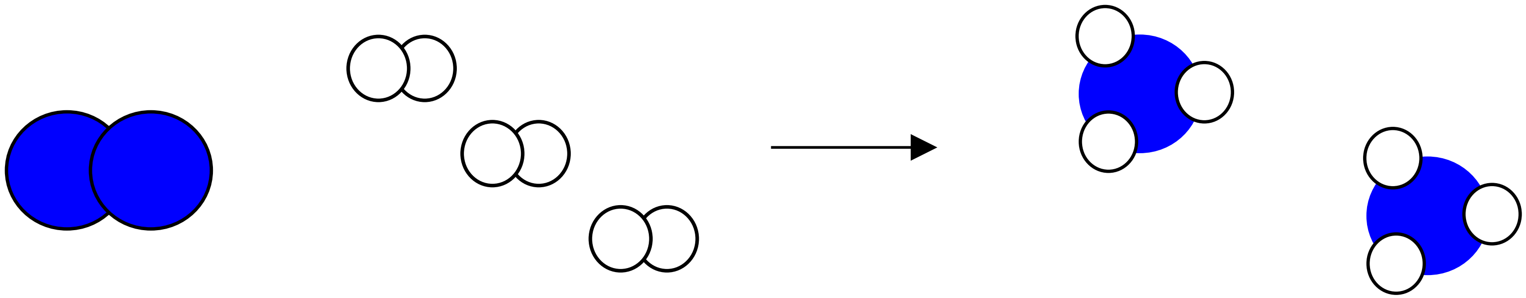
∴ there is not enough H_2 so the amount that reacts is limited by moles H_2

∴ H_2 is limiting reagent (and N_2 is in excess)

∴ so only 1 mole of N_2 can react (and 2 moles of N_2 is left over)

	N_2	H_2	NH_3
CHANGES	–1 mole	–3 moles	+2 moles
END	3–1 = 2 moles	3–3 = 0 moles	0+2 = 2 moles

LIMITING REAGENTS



$$N_2 + 3\,H_2 \longrightarrow 2\,NH_3$$

	N_2	$3\,H_2$	$2\,NH_3$
START	1 mole	10 moles	

1 mole of N_2 needs 3 moles of H_2 for it all to react

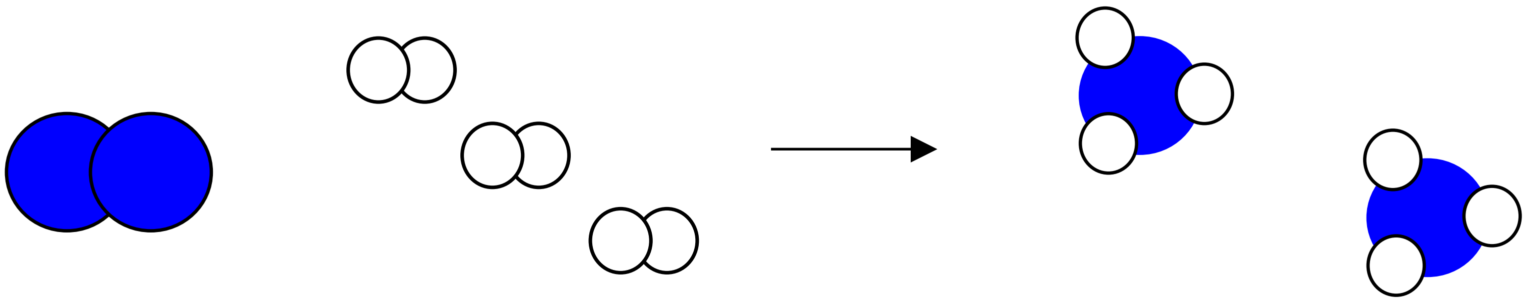
∴ there is more than enough H_2 not all of the H_2 reacts

∴ N_2 is limiting reagent (and H_2 is in excess)

so only 3 mole of H_2 can react (and 7 moles of H_2 is left over)

	N_2	$3\,H_2$	$2\,NH_3$
CHANGES	–1 mole	–3 moles	+2 moles
END	1–1 = 0 moles	10–3 = 7 moles	0+2 = 2 moles

LIMITING REAGENTS



$$N_2 + 3\,H_2 \longrightarrow 2\,NH_3$$

	N_2	H_2	NH_3
START	12 moles	24 moles	

12 moles of N_2 needs 36 moles of H_2 for it all to react

$\therefore$ there is not enough H_2 so the amount that reacts is limited by moles H_2

$\therefore$ H_2 is limiting reagent (and N_2 is in excess)

$\therefore$ so only 8 moles of N_2 can react (and 4 moles of N_2 is left over)

	N_2	H_2	NH_3
CHANGES	–8 mole	–24 moles	+16 moles
END	12-8 = 4 moles	24-24 = 0 moles	0+16 = 16 moles

LIMITING REAGENTS

$$2\,SO_2 + O_2 \longrightarrow 2\,SO_3$$

	$2\,SO_2$	O_2	$2\,SO_3$
START	10 moles	8 moles	

10 moles of SO_2 needs 5 moles of O_2 for it all to react

$\therefore$ there is more than enough O_2

$\therefore$ SO_2 is limiting reagent (and O_2 is in excess)

$\therefore$ so only 5 moles of O_2 can react (and 3 moles of O_2 is left over)

	$2\,SO_2$	O_2	$2\,SO_3$
CHANGES	–10 mole	–5 moles	+10 moles
END	10–10 = 0 moles	8–5 = 3 moles	0+16 = 10 moles

IDEAL GAS EQUATION

$$PV = nRT$$

P = Pressure (Pa)

V = Volume (m^3)

n = number of moles

R = Gas Constant (8.31 J mol^{-1} K^{-1})

T = Temperature (K)

Pressure units

1kPa = 1 000 Pa	kPa x 10^3 = Pa
1MPa = 1 000 000 Pa	MPa x 10^6 = Pa

Volume units

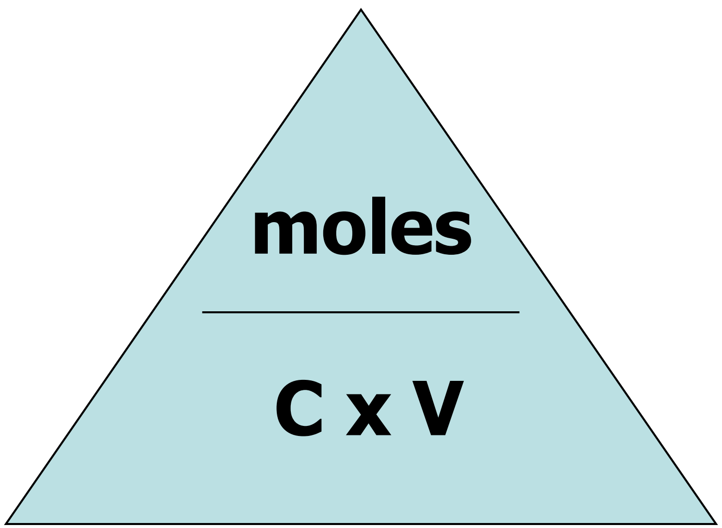
1 dm^3 = 10^{-3} m^3	$\frac{dm^3}{10^3} = m^3$
1 cm^3 = 10^{-6} m^3	$\frac{cm^3}{10^6} = m^3$

Temperature units

T(K) = 273 + T(°C)

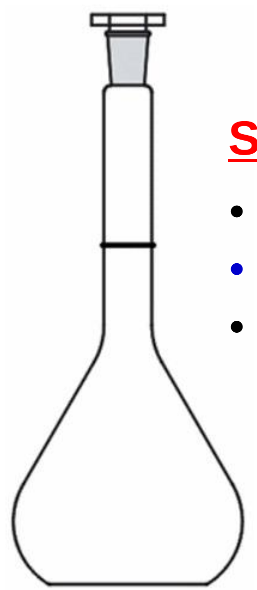
SOLUTIONS

$$\text{concentration (mol dm}^{-3}\text{)} = \frac{\text{moles}}{\text{volume (dm}^3\text{)}}$$



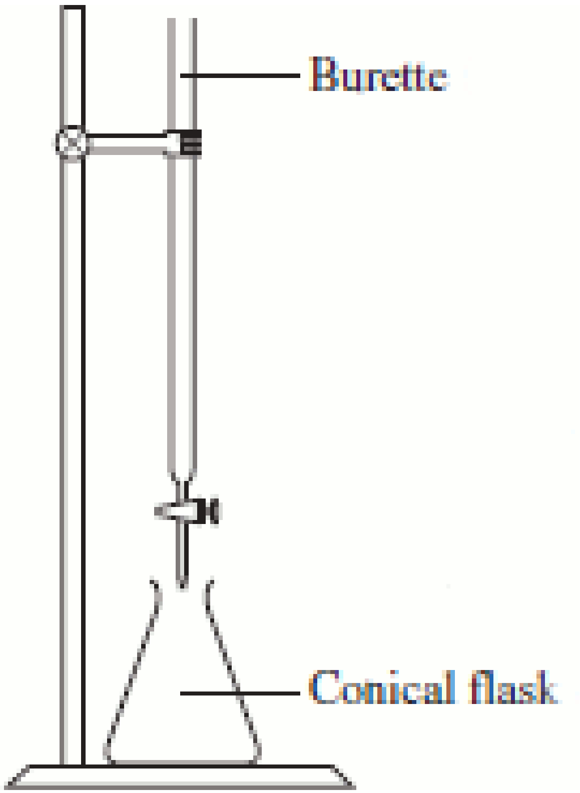
BACK TITRATIONS

Used to analyse insoluble bases (we have to work backwards).



STEP 1

- place sample in volumetric flask
- **add excess acid/base**
- make up to 250 cm^3



STEP 2

- remove 25 cm^3 by pipette
- titrate excess acid/base against solution of known concentration
- repeat titration to get concordant results

BACK TITRATIONS

Used to analyse insoluble acids/bases (we have to work backwards).

Imagine that we are trying to find out how many moles of $CaCO_3$ we have (let's call it x moles).

We add 10.0 moles of HCl (an excess). The excess HCl is made into a 250 cm^3 stock solution and then 25 cm^3 portions of it require 0.40 moles of NaOH for neutralisation.

$CaCO_3 + 2\,HCl \rightarrow CaCl_2 + H_2O + CO_2$

x   10.0

10.0 added – 4.0 left over

= 6.0 reacted with $CaCO_3$

3.0

left over

$HCl + NaOH \rightarrow NaCl + H_2O$

0.40   0.40   per titration

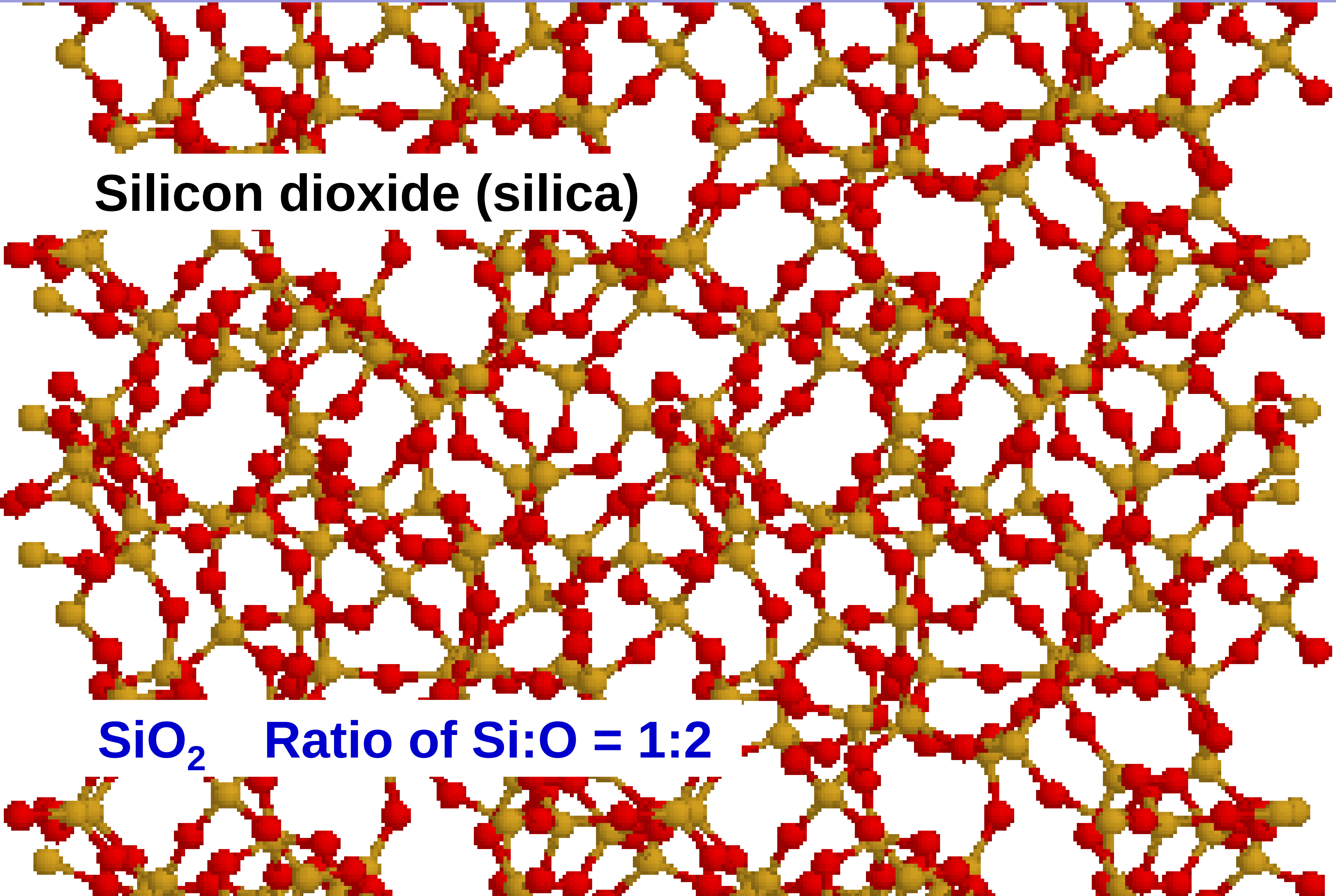
4.0 in whole stock solution

∴there are 10 x 0.40 moles (= 4.0 moles) of left over HCl in the stock solution

∴6.0 moles (10.0 – 4.0 moles) of HCl reacted with the $CaCO_3$

∴there must have been 3.0 moles of $CaCO_3$ (i.e. x = 3.0) in the first place (remember that 2 moles of HCl reacts with 1 mole of $CaCO_3$).

EMPIRICAL FORMULAE

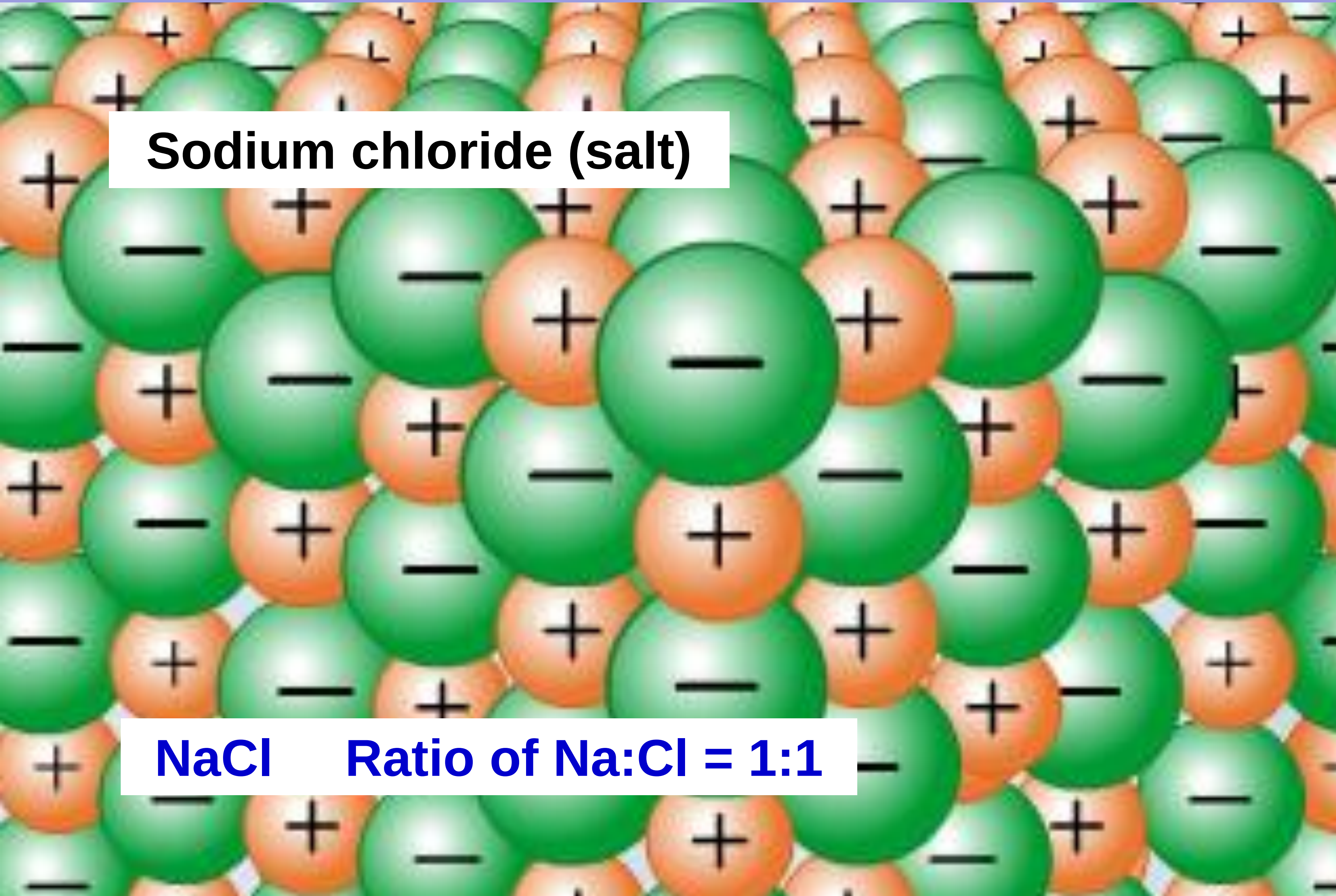


Silicon dioxide (silica)

SiO_2 Ratio of Si:O = 1:2

EMPIRICAL FORMULAE

Sodium chloride (salt)

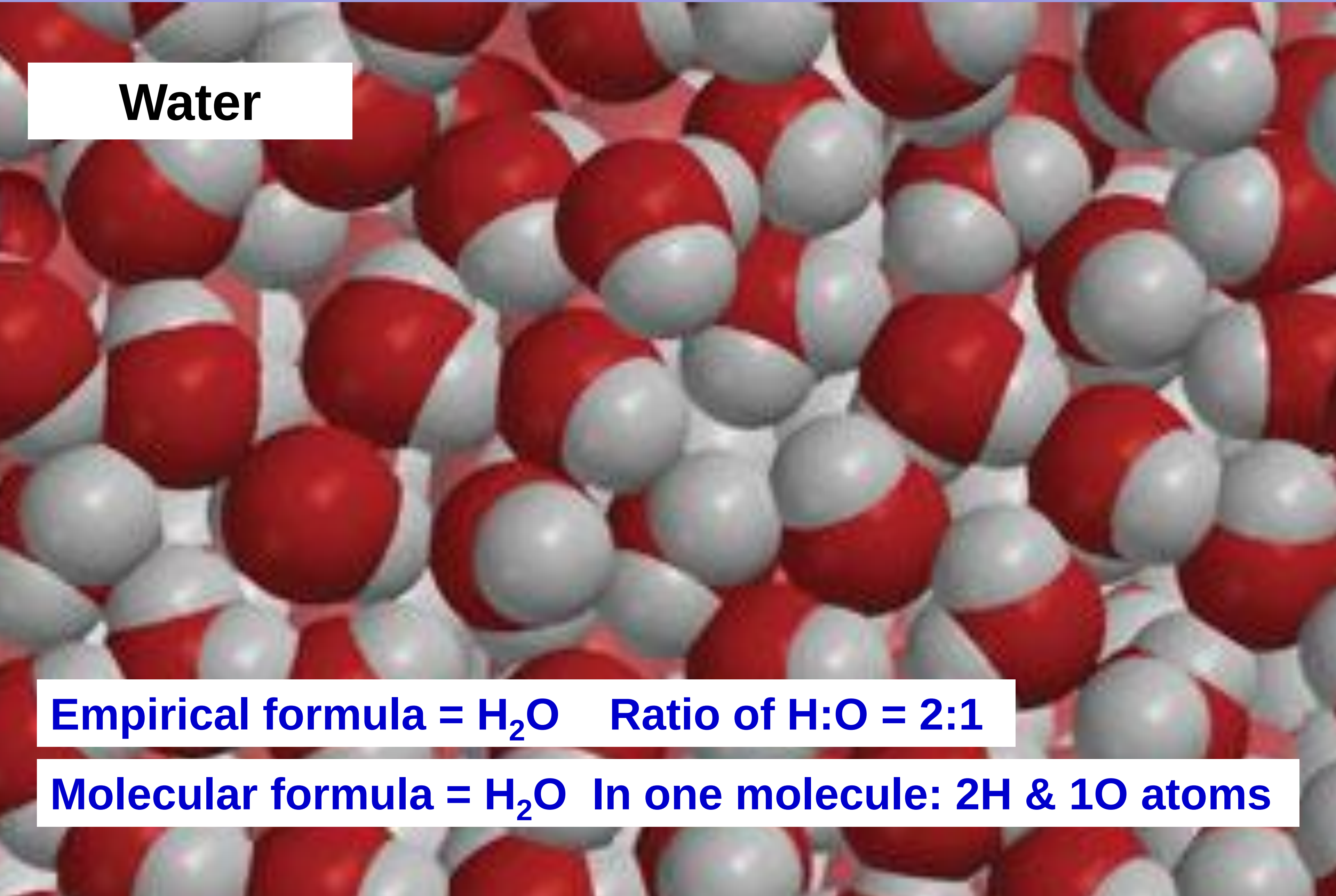


NaCl   Ratio of Na:Cl = 1:1

EMPIRICAL FORMULAE

- **All substances have an empirical formula**
- **It gives the simplest ratio of atoms/ions of each element in a substance**
- **For most substances it is the ONLY formula (substances made of molecules also have a second formula – the molecular formula)**

EMPIRICAL FORMULAE

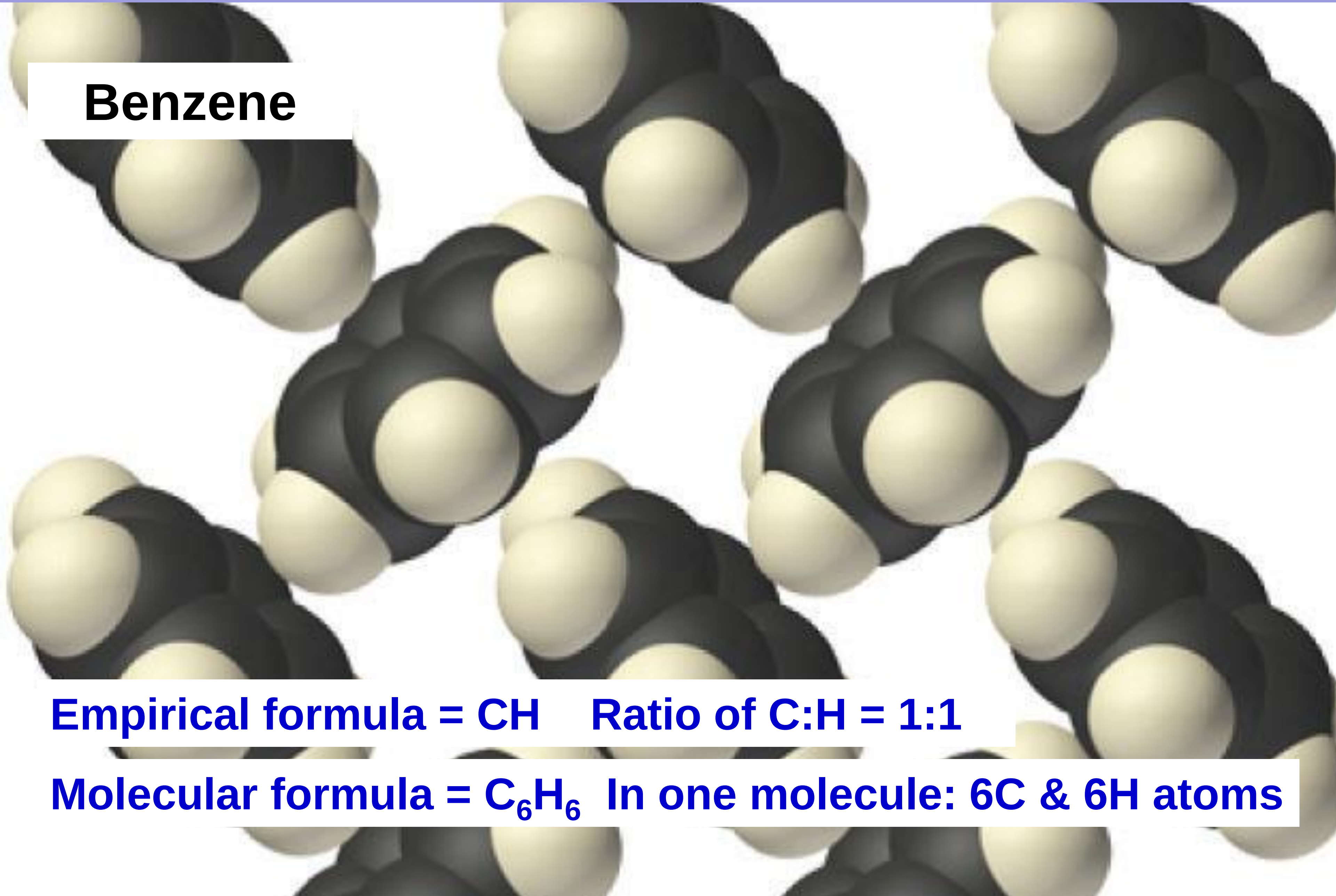


Water

Empirical formula = H_2O Ratio of H:O = 2:1

Molecular formula = H_2O In one molecule: 2H & 1O atoms

EMPIRICAL FORMULAE



Benzene

Empirical formula = CH   Ratio of C:H = 1:1

Molecular formula = C_6H_6 In one molecule: 6C & 6H atoms