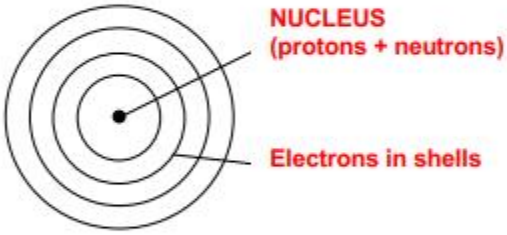
ATOMIC STRUCTURE

Atoms consist of a central **NUCLEUS** containing protons and **NEUTRONS**. The nucleus is **TINY** compared to the size of the whole atom. The nucleus is surrounded by **ELECTRONS** in energy levels (also called **SHELLS**). Atoms have no electric charge because they contain the same number of protons and **ELECTRONS**.

sub-atomic particle	relative mass	relative charge
proton	1	+1
neutron	1	0
electron	0.0005 or $\frac{1}{1836}$	-1



Atomic number = number of **PROTONS**

Mass number = number of **PROTONS** + number of **NEUTRONS**

The number of protons, neutrons and electrons in an atom can be worked out using the atomic number and mass number.

Number of protons = **ATOMIC NUMBER**

Number of neutrons = **MASS NUMBER - ATOMIC NUMBER**

Number of electrons = **ATOMIC NUMBER**

Atoms can be represented as follows:

$^{\text{mass number}}_{\text{atomic number}}\textbf{Symbol}$ e.g. $^{19}_{9}F$ protons = **9** neutrons = **10** electrons = **9**

Atoms of the same element have the same number of **PROTONS.** In fact, it is the number of **PROTONS** that determines what type of atom it is (e.g. all atoms with 6 protons are carbon atoms). Atoms of different elements have different numbers of **PROTONS**.

Isotopes are atoms with the same number of **PROTONS** but a different number of **NEUTRONS** . This means they are atoms of the same **ELEMENT** with the same **ATOMIC** number but a different **MASS** number.

	$^{35}_{17}Cl$	$^{37}_{17}Cl$
protons	17	17
neutrons	18	20
electrons	17	17

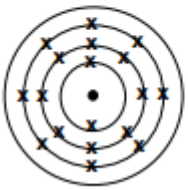
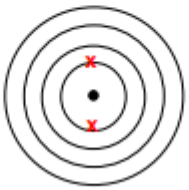
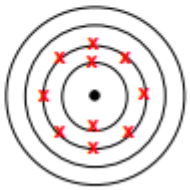
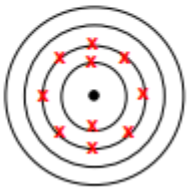
Atom	Atomic number	Mass number	Number of protons	Number of neutrons	Number of electrons
$^{23}_{11}Na$	11	23	11	12	11
$^{7}_{3}Li$	3	7	3	4	3
$^{40}_{18}Ar$	18	40	18	22	18
$^{39}_{19}K$	19	39	19	20	19
$^{27}_{13}Al$	13	27	13	14	13
$^{235}_{92}U$	92	235	92	143	92
$^{238}_{92}U$	92	238	92	146	92

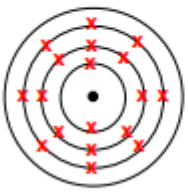
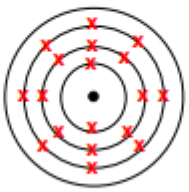
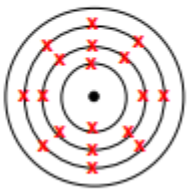
IONS

1) Complete the table below to show whether particles are atoms or ions, and for ions their charge.

Number and overall charge of protons	11+	11+	16+	4+	13+	18+	17+	15+	21+	1+	32+	35+
Number and overall charge of electrons	11–	10–	18–	2–	10–	18–	18–	18–	18–	0–	32–	36–
Atom or ion?	atom	ion	ion	ion	ion	atom	ion	ion	ion	ion	atom	ion
Overall charge		1+	2–	2+	3+		1–	3–	3+	1+		1–

2) Complete the table below to show the electronic structure of some common ions. The first one has been done for you. You will need to use the Periodic Table to help.

Ion	Cl^-	Li^+	F^-	Mg^{2+}
Protons	17	3	9	12
Electrons	18	2	10	10
Electron structure				
Electron structure	2,8,8	2	2,8	2,8

Ion	K^+	S^{2-}	H^+	P^{3-}
Protons	19	16	1	15
Electrons	18	18	0	18
Electron structure				
Electron structure	2,8,8	2,8,8	0	2,8,8

ATOMS & IONS 1

Species	Atom / ion	Atomic number	Mass number	Number of protons	Number of neutrons	Number of electrons
$^{14}_{7}N$	atom	7	14	7	7	7
$^{31}_{15}P$	atom	15	31	15	16	15
$^{7}_{3}Li$	atom	3	7	3	4	3
$^{20}_{10}Ne$	atom	10	20	10	10	10
$^{40}_{20}Ca$	atom	20	40	20	20	20
$^{40}_{18}Ar$	atom	18	40	18	22	18
$^{9}_{4}Be$	atom	4	9	4	5	4
$^{208}_{82}Pb$	atom	82	208	82	126	82
$^{79}_{35}Br$	atom	35	79	35	44	35
$^{81}_{35}Br$	atom	35	81	35	46	35
$^{23}_{11}Na^{+}$	ion	11	23	11	12	10
$^{16}_{8}O$	atom	8	16	8	8	8
$^{16}_{8}O^{2-}$	ion	8	16	8	8	10
$^{35}_{17}Cl^{-}$	ion	17	35	17	18	18
$^{39}_{19}K$	atom	19	39	19	20	19
$^{39}_{19}K^{+}$	ion	19	39	19	20	18
$^{40}_{20}Ca^{2+}$	ion	20	40	20	20	18
$^{1}_{1}H^{+}$	ion	1	1	1	0	0
$^{127}_{53}I^{-}$	ion	53	127	53	74	54
$^{14}_{7}N^{3-}$	ion	7	14	7	7	10

ATOMIC STRUCTURE (C)

1 Complete the table about these atoms and ions.

atom / ion	protons	neutrons	electrons	electron structure
$^{27}_{13}Al$	13	14	13	2,8,3
$^{27}_{13}Al^{3+}$	13	14	10	2,8
$^{17}_{8}O$	8	9	8	2,6
$^{17}_{8}O^{2-}$	8	9	10	2,8

2 The electron structure of some atoms are given. Which group of the Periodic Table does each of these atoms belong to?

electron structure	2,8,7	2,8,8,1	2,8,18,3	2,8,18,18,6	2,8
group	7	1	13	6	8 / 0

3 There are two isotopes of boron, which are shown in the table.

isotope	$^{10}_{5}B$	$^{11}_{5}B$
abundance	19.9%	80.1%

a Explain why they are both atoms of boron. **both contain 5 protons**

b The radius of a boron atom is 180 pm. Write this in metres in standard form. **1.8×10^{-10} m**

c Calculate the relative atomic mass of boron to 3 significant figures.

$$\text{relative atomic mass} = \frac{(10 \times 19.9)+(11 \times 80.1)}{19.9+80.1} = 10.8$$

NAMING SUBSTANCES 2

Name the following substances.

Formula	Name
O_2	Oxygen
CuO	Copper oxide
Cu	Copper
$CuSO_4$	Copper sulfate
CuS	Copper sulfide
$CuCO_3$	Copper carbonate
$FeSO_4$	Iron sulfate
$Fe(NO_3)_2$	Iron nitrate
N_2	nitrogen
H_2SO_4	Sulfuric acid
CO	Carbon monoxide
CO_2	Carbon dioxide
NO_2	Nitrogen dioxide (nitrogen oxide)
HCl	Hydrochloric acid
$KHCO_3$	Potassium hydrogencarbonate
K_2CO_3	Potassium carbonate
Mg	Magnesium
AgF	Silver fluoride
$Ca(OH)_2$	Calcium hydroxide
$CaCO_3$	Calcium carbonate

Name	Formula
Al_2O_3	Aluminium oxide
Na	Sodium
$Al_2(SO_4)_3$	Aluminium sulfate
HNO_3	Nitric acid
I_2	Iodine
Ni	Nickel
Al	Aluminium
Na_2O	Sodium oxide
NaOH	Sodium hydroxide
NaBr	Sodium bromide
Na_2CO_3	Sodium carbonate
He	Helium
CH_4	methane
NH_3	Ammonia
NH_4Br	Ammonium bromide
H_2Te	Hydrogen telluride
$SnCl_4$	Tin chloride
WO_3	Tungsten oxide
HgO	Mercury oxide
TiC	Titanium carbide

WORD EQUATIONS 1

1) $2\ Mg + O_2 \rightarrow 2\ MgO$

Magnesium + oxygen → magnesium oxide

2) $2\ K + Br_2 \rightarrow 2\ KBr$

Potassium + bromine → potassium bromide

3) $Cu + S \rightarrow CuS$

Copper + sulfur → copper sulfide

4) $CuCO_3 \rightarrow CuO + CO_2$

Copper carbonate → copper oxide + carbon dioxide

5) $PbI_2 \rightarrow Pb + I_2$

Lead iodide → lead + iodine

6) $CuBr_2 \rightarrow Cu + Br_2$

Copper bromide → copper + bromine

7) $Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$

Zinc + sulfuric acid → zinc sulfate + hydrogen

8) $Na_2CO_3 + H_2SO_4 \rightarrow Na_2SO_4 + CO_2 + H_2O$

Sodium carbonate + sulfuric acid → sodium sulfate + carbon dioxide + water

9) $KBr + AgNO_3 \rightarrow AgBr + KNO_3$

Potassium bromide + silver nitrate → silver bromide + potassium nitrate

10) $MgSO_4 + Ba(NO_3)_2 \rightarrow BaSO_4 + Mg(NO_3)_2$

Magnesium sulfate + barium nitrate → barium sulfate + magnesium nitrate

BALANCING EQUATIONS 1

1) $2\,Ca + O_2 \rightarrow 2\,CaO$

2) $Na_2O + H_2O \rightarrow 2\,NaOH$

3) $4\,Al + 3\,O_2 \rightarrow 2\,Al_2O_3$

4) $2\,Na + Cl_2 \rightarrow 2\,NaCl$

5) $Na_2CO_3 \rightarrow Na_2O + CO_2$

6) $4\,K + O_2 \rightarrow 2\,K_2O$

7) $C_4H_8 + 6\,O_2 \rightarrow 4\,CO_2 + 4\,H_2O$

8) $Fe_2O_3 + 6\,HCl \rightarrow 2\,FeCl_3 + 3\,H_2O$

9) $F_2 + 2\,KBr \rightarrow 2\,KF + Br_2$

10) $C_5H_{12} + 8\,O_2 \rightarrow 5\,CO_2 + 6\,H_2O$

11) $4\,NH_3 + 5\,O_2 \rightarrow 4\,NO + 6\,H_2O$

12) $4\,HNO_3 \rightarrow 4\,NO_2 + 2\,H_2O + O_2$

IONIC COMPOUNDS 2

1) electrons, lose, positive, gain, negative

2) copper oxide, zinc bromide

3) a) Mg^{2+} = 2,8, O^{2-} = 2,8
   b) the ratio of Mg^{2+} ions to O^{2-} ions in magnesium oxide is 1:1

4) a) strong electrostatic attraction between positive and negative ions
   b) ions can move and carry charge
   c) ions cannot move

5) C, D

IONIC FORMULAE 1

1

a) NaI
b) K_2O
c) $AlCl_3$
d) $MgBr_2$
e) Al_2O_3
f) FeO
g) Fe_2O_3
h) MgS
i) CuF_2
j) LiI
k) $BaBr_2$
l) ZnS
m) PbI_2
n) Fe_2S_3
o) MgO
p) RbBr
q) $SrCl_2$
r) CsSe
s) $CaAt_2$
t) RaPo
u) GaF_3
v) $ScBr_3$
w) Cr_2O_3
x) SrI_2
y) Li_3As

2

a) Na_2SO_4
b) $CaSO_4$
c) $Mg(OH)_2$
d) $Zn(NO_3)_2$
e) $CuCO_3$
f) NaOH
g) K_2CO_3
h) $Fe(OH)_3$
i) NH_4NO_3
j) NH_4OH
k) $Fe_2(SO_4)_3$
l) $Al(NO_3)_3$
m) $AgNO_3$
n) $CaCO_3$
o) $Mg(NO_3)_2$
p) NH_4At
q) $CsNO_3$
r) $Sr(OH)_2$
s) $Pt(NO_3)_2$
t) $CoCO_3$
u) Cu_2O
v) CuO
w) Fr_2Te
x) AuF
y) Rb_2SO_4

DRAWING MOLECULES 1

When non-metals combine with other non-metals, the atoms share electrons to form a molecule. The atoms are held together by these shared electrons which are known as covalent bonds.

Molecule = a particle made up of atoms joined by covalent bonds

Covalent bond = 2 shared electrons

How many covalent bonds?

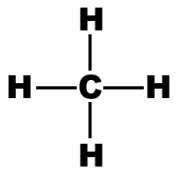
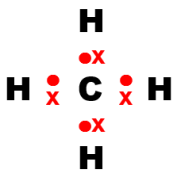
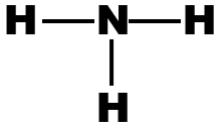
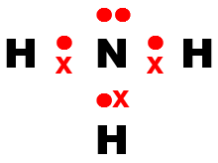
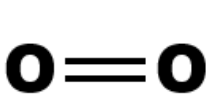
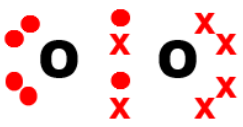
Atoms	Number of electrons in outer shell	Number of extra electrons needed to fill the outer shell	Number of covalent bonds formed
Group 7 (e.g. F, Cl, Br, I)	7	1	1
Group 6 (e.g. O, S)	6	2	2
Group 5 (e.g. N, P)	5	3	3
Group 4 (e.g. C, Si)	4	4	4
H	1	1	1

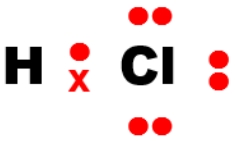
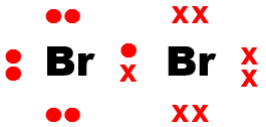
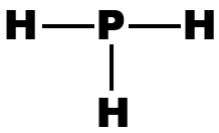
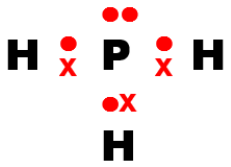
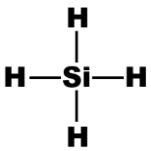
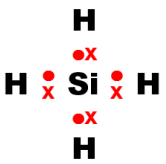
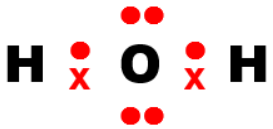
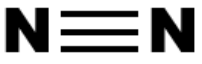
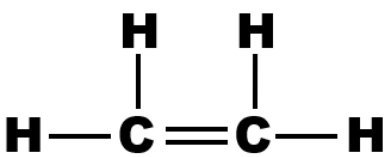
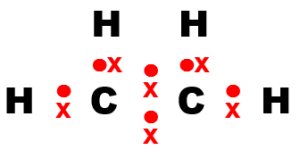
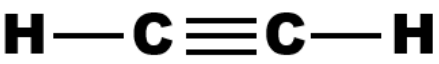
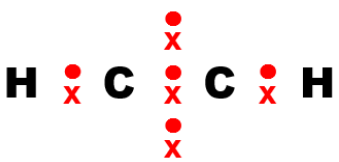
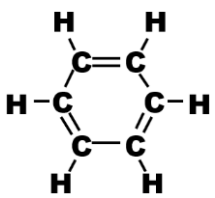
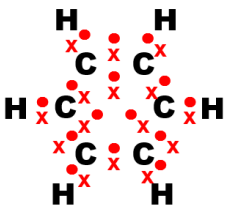
Drawing stick diagrams & dot-cross diagrams

Stick diagrams – these show each covalent bond as a stick.

Dot-cross diagrams – these show the outer shell electrons only

1. Draw a stick diagram
2. Re-draw the stick diagram without the sticks
3. Replace the stick with a **X●** which represents the two electrons in the bond (**X** represents electrons from one atom, and ● represents the electron from the other atom).
4. Add in any other outer shell electrons from each atom (electrons are always in pairs)
5. CHECK that there are 8 electrons around each atom (except H where there should be 2 electrons)

Stick diagram	Molecule	Dot-cross diagram
	CH_4	
	NH_3	
	O_2	

	HCl	
	Br_2	
	PH_3	
	CO_2	
	SiH_4	
	H_2O	
	N_2	
	C_2H_4	
	C_2H_2	
	C_6H_6	

PROPERTIES OF STRUCTURE TYPES

Property	Monatomic	Ionic	Simple molecular	Giant covalent	Metallic	
Melting and boiling points	Very low	High	Low	Very high	High	Very high High High Low Very low
Conductivity as solid	does not conduct	does not conduct	does not conduct	some conduct, some don't	conducts	conducts some conduct, some don't does not conduct does not conduct does not conduct
Conductivity when melted	does not conduct	conducts	does not conduct	does not conduct	conducts	conducts conducts does not conduct does not conduct does not conduct
Solubility in water	insoluble	soluble (usually)	insoluble (usually)	insoluble	insoluble	soluble (usually) insoluble (usually) insoluble insoluble insoluble
Conductivity of solution	insoluble	conducts	insoluble (usually)	insoluble	insoluble	conducts insoluble (usually) insoluble insoluble insoluble

STRUCTURE TYPES 1

1) Which type of structure do the following substances have?

	K_2O	K	O_2	CH_2O	Ar	S_8	Br_2	Cr	FeI_3	$MgSO_4$	N_2H_4
ionic	✓								✓	✓	
simple molecular			✓	✓		✓	✓				✓
metallic		✓						✓			
monatomic					✓						
giant covalent											

2) Look at the properties of the following substances.

Substance	Melting point (°C)	Boiling point (°C)	Electrical conductivity as	
			solid	liquid
A	587	843	does not conduct	conducts
B	28	201	does not conduct	does not conduct
C	-39	357	conducts	conducts
D	-189	-101	does not conduct	does not conduct
E	2157	2895	does not conduct	does not conduct
F	1024	1598	does not conduct	conducts

a) Which of these compounds could have an ionic structure? ..... A F .....

b) Which of these compounds could have a simple molecular structure? ..... B D .....

c) Which of these compounds could have a metallic structure? ..... C .....

d) Which of these compounds could have a giant covalent structure? ..... E .....

3) Write the formula of the following ionic compounds.

a) potassium oxide ..K_2O.....

b) magnesium nitrate ..$Mg(NO_3)_2$..

c) aluminium hydroxide ..$Al(OH)_3$..

d) copper carbonate ..$CuCO_3$..

e) ammonium hydroxide ..NH_4OH..

f) iron (III) oxide ..Fe_2O_3...

5) a) Aluminium oxide is an ionic substance with formula Al_2O_3. Explain what this formula means.

✓ ratio of Al^{3+} : O^{2-} ions = 2 : 3

b) Explain why aluminium oxide has a high melting point.

✓ strong attraction ✓ between ions of opposite charge

c) Explain why aluminium oxide does not conduct electricity as a solid but does when melted.

solid: ✓ ions cannot move

molten: ✓ ions can move

4) a) Aluminium is a metal. Explain why it has a high melting point.

✓ strong attraction between +ve metal ions and delocalised electrons

b) Explain why aluminium conducts electricity.

✓ outer shell ✓ electrons ✓ delocalised

6) a) Ammonia is a simple molecular substance with formula NH_3. Explain what this formula means.

✓ in one molecule

✓ 1 N + 3 H atoms

b) Explain why ammonia has a low melting point.

✓ weak forces ✓ between molecules

c) Explain why ammonia does not conduct electricity in any state.

✓ molecules neutral

7) a) Explain why diamond is hard but graphite is soft.

diamond ✓ rigid network of atoms

graphite ✓ layers of atoms – layers not joined to each other

b) Explain why graphite conducts electricity but diamond does not.

diamond ✓ no delocalised electrons

graphite ✓ delocalised electrons

RELATIVE FORMULA MASS

Calculate the relative formula mass of the following substances.

1	F_2		2(19)	= 38
2	Fe			= 56
3	H_2SO_4		2(1) + 32 + 4(16)	= 98
4	Al_2O_3		2(27) + 3(16)	= 102
5	$Mg(OH)_2$		24 + 2(16) + 2(1)	= 58
6	$Al(NO_3)_3$		27 + 3(14) + 9(16)	= 213
7	$(NH_4)_2SO_4$		2(14) + 8(1) + 32 + 4(16)	= 132
8	$CuCO_3$		63.5 + 12 + 3(16)	= 123.5
9	$AgNO_3$		108 + 14 + 3(16)	= 170
10	NH_4NO_3		14 + 4(1) + 14 + 3(16)	= 80
11	$CuSO_4.5H_2O$		63.5 + 32+ 4(16) + 10(1) + 5(16)	= 249.5
12	magnesium	Mg	24	= 24
13	oxygen	O_2	2(16)	= 32
14	sodium bromide	NaBr	23 + 80	= 103
15	calcium fluoride	CaF_2	40 + 2(19)	= 78
16	potassium sulfate	K_2SO_4	2(39) + 32 + 4(16)	= 174
17	chlorine	Cl_2	2(35.5)	= 71
18	chromium(III) oxide	Cr_2O_3	2(52) + 3(16)	= 152
19	sodium	Na		= 23
20	iron(III) sulfate	$Fe_2(SO_4)_3$	2(56) + 3(32) + 12(16)	= 400

PERCENTAGE MASS

You can find the percentage by mass of an element in a compound.

e.g. % by mass of Fe in Fe_2O_3 = $100 \times \frac{2(56)}{160}$ = 70%

1 % by mass of O in H_2O — **% O in H_2O = $100 \times \frac{16}{18}$ = 88.9%**

2 % by mass of O in SO_3 — **% O in SO_3 = $100 \times \frac{3(16)}{80}$ = 60%**

3 % by mass of Na in Na_2CO_3 — **% Na in Na_2CO_3 = $100 \times \frac{2(23)}{106}$ = 43.4%**

4 % by mass of N in $Ca(NO_3)_2$ — **% N in $Ca(NO_3)_2$ = $100 \times \frac{2(14)}{164}$ = 17.1%**

5 % by mass of O in $Ca(NO_3)_2$ — **% O in $Ca(NO_3)_2$ = $100 \times \frac{6(16)}{164}$ = 58.5%**

6 % by mass of Cl in $FeCl_3$ — **% Cl in $FeCl_3$ = $100 \times \frac{3(35.5)}{162.5}$ = 65.5%**

7 % by mass of N in NH_4NO_3 — **% N in NH_4NO_3 = $100 \times \frac{2(14)}{80}$ = 35%**

8 % by mass of S in $Al_2(SO_4)_3$ — **% S in $Al_2(SO_4)_3$ = $100 \times \frac{3(32)}{342}$ = 28.1%**

9 % by mass of Li in lithium oxide — **% Li in Li_2O = $100 \times \frac{2(7)}{30}$ = 46.7%**

10 % by mass of Cr in chromium(III) oxide — **% Cr in Cr_2O_3 = $100 \times \frac{2(52)}{152}$ = 68.4%**

11 % by mass of O in calcium hydroxide — **% O in $Ca(OH)_2$ = $100 \times \frac{2(16)}{74}$ = 43.2%**

12 % by mass of N in ammonium iodide — **% N in NH_4I = $100 \times \frac{14}{145}$ = 9.7%**

13 % by mass of O in $CuSO_4.5H_2O$ — **% O in $CuSO_4.5H_2O$ = $100 \times \frac{9(16)}{249.5}$ = 57.7%**

MOLES

1) Calculate the number of moles of each of the following substances. Give your answers to 3 significant figures.

a) 90.0 g of H_2O — $\frac{90.0}{18} = 5.00$

b) 20.0 g of C_4H_{10} — $\frac{20.0}{58} = 0.345$

c) 685 g of NH_3 — $\frac{685}{17} = 40.3$

d) 102 tons of O_2 — $\frac{102000000}{32} = 3190000\ (3.19 \times 10^6)$

e) 2.00 kg of Al_2O_3 — $\frac{2000}{102} = 19.6$

f) 20.6 mg of Au — $\frac{0.0206}{197} = 0.000105\ (1.05 \times 10^{-4})$

2) Calculate the mass of each of the following substances. Give your answers to 3 significant figures.

a) 4.00 moles of N_2 — $4.00 \times 28 = 112$ g

b) 0.100 moles of HNO_3 — $0.100 \times 63 = 6.30$ g

c) 0.0200 moles of K_2O — $0.0200 \times 94 = 1.88$ g

d) 2.50 moles of PH_3 — $2.50 \times 34 = 85.0$ g

e) 0.400 moles of C_2H_5OH — $0.400 \times 46 = 18.4$ g

f) 10.0 moles of $Ca(OH)_2$ — $10.0 \times 74 = 740$ g

3) 0.0200 moles of a compound is found to have a mass of 1.64 g. Find the formula mass of the compound.

Formula mass $= \frac{1.64}{0.0200} = 82.0$

MOLAR RATIOS

A balanced equation shows us how many moles of each substance are used or produced in a chemical reaction. Complete the questions in a similar way to the example which has been done for you.

EXAMPLE	C_3H_8	+	$5O_2$	→	$3CO_2$	+	$4H_2O$
what it means	1 mol of C_3H_8		5 mol of O_2		3 mol of CO_2		4 mol of H_2O
a)	2 mol		10 mol		6 mol		8 mol
b)	10 mol		50 mol		30 mol		40 mol
c)	0.5 mol		2.5 mol		1.5 mol		2.0 mol

1	$2Ca$	+	O_2	→	$2CaO$
what it means	**2 mol of Ca**		**1 mol of O_2**		**2 mol of CaO**
a)	4 mol		**2 mol**		**4 mol**
b)	**10 mol**		5 mol		**10 mol**
c)	0.10 mol		**0.05 mol**		**0.10 mol**

2	$2Fe$	+	$3Cl_2$	→	$2FeCl_3$
what it means	**2 mol of Fe**		**3 mol of Cl_2**		**2 mol of $FeCl_3$**
a)	10 mol		**15 mol**		**10 mol**
b)	**6 mol**		9 mol		**6 mol**
c)	**0.40 mol**		0.60 mol		**0.40 mol**

3	$TiCl_4$	+	$4Na$	→	Ti	+	$4NaCl$
what it means	**1 mol of $TiCl_4$**		**4 mol of Na**		**1 mol of Ti**		**4 mol of NaCl**
a)	3 mol		**12 mol**		**3 mol**		**12 mol**
b)	**2.5 mol**		10 mol		**2.5 mol**		**10 mol**
c)	0.020 mol		**0.080 mol**		**0.020 mol**		**0.080 mol**

4	$2Al_2O_3$	→	$4Al$	+	$3O_2$
what it means	**2 mol of Al_2O_3**		**4 mol of Al**		**3 mol of O_2**
a)	5 mol		**10 mol**		**7.5 mol**
b)	**0.050 mol**		0.100 mol		**0.075 mol**
c)	**40 mol**		**80 mol**		60 mol

5	C_2H_5OH	+	$3O_2$	→	$2CO_2$	+	$3H_2O$
what it means	**1 mol of C_2H_5OH**		**3 mol of O_2**		**2 mol of CO_2**		**3 mol of H_2O**
a)	**4 mol**		12 mol		**8 mol**		**12 mol**
b)	0.25 mol		**0.75 mol**		**0.50 mol**		**0.75 mol**
c)	**0.05 mol**		**0.15 mol**		0.10 mol		**0.15 mol**

1) What mass of oxygen reacts with 12 g of magnesium?

✓ ?

$$2Mg + O_2 \rightarrow 2MgO$$

Moles Mg = $\frac{\text{mass}}{M_r} = \frac{12}{24} = 0.5$

Moles O_2 = 0.25

Mass O_2 = M_r x moles = 32 x 0.25 = **8 g**

2) What mass of calcium hydroxide is made from 14 kg of calcium oxide?

✓ ?

$$CaO + H_2O \rightarrow Ca(OH)_2$$

Moles CaO = $\frac{\text{mass}}{M_r} = \frac{14000}{56} = 250$

Moles $Ca(OH)_2$ = 250

Mass $Ca(OH)_2$ = M_r x moles = 74 x 250 = **18500 g**

3) What mass of aluminium is needed to react with 640 g of iron oxide?

✓ ?

$$Fe_2O_3 + 2\,Al \rightarrow 2\,Fe + Al_2O_3$$

Moles Fe_2O_3 = $\frac{\text{mass}}{M_r} = \frac{640}{160} = 4$

Moles Al = 8

Mass Al = M_r x moles = 27 x 8 = **216 g**

4) What mass of titanium chloride reacts with 460 g of sodium?

? ✓

$$TiCl_4 + 4\,Na \rightarrow Ti + 4\,NaCl$$

Moles Na = $\frac{\text{mass}}{M_r} = \frac{460}{23} = 20$

Moles $TiCl_4$ = 5

Mass $TiCl_4$ = M_r x moles = 190 x 5 = **950 g**

REACTING MASS CALCULATIONS 3

1) Calculate the mass of calcium that can react with 40 g of oxygen.

$2Ca + O_2 \rightarrow 2CaO$

moles $O_2 = \frac{mass}{M_r} = \frac{40}{32} = 1.25$ mol

moles Ca = 2 x 1.25 = 2.50 mol

mass Ca = M_r x moles = 40 x 2.50 = 100 g

2) Calculate the mass of fluorine that reacts with 3.9 g of potassium.

$2K + F_2 \rightarrow 2KF$

moles $K = \frac{mass}{M_r} = \frac{3.9}{39} = 0.10$ mol

moles $F_2 = \frac{0.10}{2} = 0.050$ mol

mass F_2 = M_r x moles = 38 x 0.050 = 1.9 g

3) Calculate the mass of nitrogen that reacts with 30 g of hydrogen.

$N_2 + 3H_2 \rightarrow 2NH_3$

moles $H_2 = \frac{mass}{M_r} = \frac{30}{2} = 15$ mol

moles $N_2 = \frac{15}{3} = 5$ mol

mass N_2 = M_r x moles = 28 x 5 = 140 g

4) What mass of carbon dioxide is made when 7.2 g of pentane (C_5H_{12}) burns in oxygen?

$C_5H_{12} + 8O_2 \rightarrow 5CO_2 + 6H_2O$

moles $C_5H_{12} = \frac{mass}{M_r} = \frac{7.2}{72} = 0.10$ mol

moles CO_2 = 5 x 0.10 = 0.50 mol

mass CO_2 = M_r x moles = 44 x 0.5 = 22 g

5) What mass of potassium can react with 4.0 g of oxygen?

$4K + O_2 \rightarrow 2K_2O$

moles $O_2 = \frac{mass}{M_r} = \frac{4.0}{32} = 0.125$ mol

moles K = 4 x 0.125 = 0.50 mol

mass K = M_r x moles = 39 x 0.5 = 19.5 g

6) What mass of chlorine reacts with 8.1 g of aluminium? $2Al + 3Cl_2 \rightarrow 2AlCl_3$

moles Al $= \frac{\text{mass}}{M_r} = \frac{8.1}{27} = 0.30$ **mol**

moles $Cl_2 = \frac{3}{2} \times 0.30 = 0.45$ **mol**

mass $Cl_2 = M_r \times$ **moles** $= 71 \times 0.45 = 31.95$ **g**

7) What mass of iron can be made from 20 kg of iron(III) oxide? $Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$

moles $Fe_2O_3 = \frac{\text{mass}}{M_r} = \frac{20000}{160} = 125$ **mol**

moles Fe $= 2 \times 125 = 250$ **mol**

mass Fe $= M_r \times$ **moles** $= 56 \times 250 = 14000$ **g**

8) What mass of hydrogen is needed to react with 31.8 mg of copper(II) oxide? $CuO + H_2 \rightarrow Cu + H_2O$

moles CuO $= \frac{\text{mass}}{M_r} = \frac{0.0318}{79.5} = 0.00040$ **mol**

moles $H_2 = 0.00040$ **mol**

mass $H_2 = M_r \times$ **moles** $= 2 \times 0.00040 = 0.00080$ **g**

9) 5.95 g of hydrated cobalt(II) chloride decompose to form 3.25 g of anhydrous cobalt(II) chloride on heating. Calculate the formula mass of hydrated cobalt(II) chloride and the value of *n*. $CoCl_2.nH_2O \rightarrow CoCl_2 + nH_2O$

moles $CoCl_2 = \frac{\text{mass}}{M_r} = \frac{3.25}{130} = 0.025$ **mol**

mass $H_2O = 5.95 - 3.25 = 2.70$ **g**

moles $H_2O = \frac{\text{mass}}{M_r} = \frac{2.70}{18} = 0.15$ **mol**

Ratio of moles $CoCl_2 : H_2O = 0.025 : 0.15 = \frac{0.025}{0.025} \quad \frac{0.150}{0.025} = 1 : 6$

$\therefore n = 6$ **(nearest whole number)**

LIMITING REAGENTS 1

In each example one of the reactants is in excess. Work out how many moles of the products are formed in each case.

1	**CaO**	**+**	**H_2O**	**→**	**$Ca(OH)_2$**			
a)	2 mol		3 mol		**2 mol**			
b)	10 mol		8 mol		**8 mol**			
c)	0.40 mol		0.50 mol		**0.40 mol**			
2	**$2Ca$**	**+**	**O_2**	**→**	**$2CaO$**			
a)	2 mol		2 mol		**2 mol**			
b)	10 mol		2 mol		**4 mol**			
c)	0.50 mol		0.20 mol		**0.4 mol**			
3	**$2Fe$**	**+**	**$3Cl_2$**	**→**	**$2FeCl_3$**			
a)	3 mol		3 mol		**2 mol**			
b)	12 mol		15 mol		**10 mol**			
c)	20 mol		40 mol		**20 mol**			
4	**$TiCl_4$**	**+**	**$4Na$**	**→**	**Ti**	**+**	**$4NaCl$**	
a)	4 mol		4 mol		**1 mol**		**4 mol**	
b)	2 mol		10 mol		**2 mol**		**8 mol**	
c)	0.5 mol		1 mol		**0.25 mol**		**1 mol**	
5	**C_2H_5OH**	**+**	**$3O_2$**	**→**	**$2CO_2$**	**+**	**$3H_2O$**	
a)	15 mol		30 mol		**20 mol**		**30 mol**	
b)	0.25 mol		1 mol		**0.5 mol**		**0.75 mol**	
c)	3 mol		6 mol		**4 mol**		**6 mol**	
6	**N_2**	**+**	**$3H_2$**	**→**	**$2NH_3$**			
a)	3 mol		6 mol		**4 mol**			
b)	0.5 mol		0.9 mol		**0.6 mol**			
c)	6 mol		20 mol		**12 mol**			
7	**$4K$**	**+**	**O_2**	**→**	**$2K_2O$**			
a)	10 mol		2 mol		**4 mol**			
b)	6 mol		4 mol		**3 mol**			
c)	0.50 mol		0.20 mol		**0.25 mol**			

LIMITING REAGENTS 2

1 What mass of calcium hydroxide is formed when 10.0 g of calcium oxide reacts with 10.0 g of water? $CaO + H_2O \rightarrow Ca(OH)_2$

Moles of CaO = $\frac{10.0}{56}$ = **0.179 mol** **Moles of H_2O** = $\frac{10.0}{18}$ = **0.556 mol**

0.179 mol of CaO reacts with 0.179 mol of H_2O, ∴ H_2O is in excess; CaO is limiting reagent

moles of $Ca(OH)_2$ formed = 0.179 mol

mass of $Ca(OH)_2$ = 74 x 0.179 = 13.2 g

2 What mass of magnesium bromide is formed when 1.00 g of magnesium reacts with 5.00 g of bromine? $Mg + Br_2 \rightarrow MgBr_2$

Moles of Mg = $\frac{1.000}{24}$ = **0.0417 mol** **Moles of Br_2** = $\frac{5.00}{160}$ = **0.03125 mol**

0.03125 mol of Mg reacts with 0.03125 mol of Br_2, ∴ Mg is in excess; Br_2 is limiting reagent

moles of $MgBr_2$ formed = 0.03125 mol

mass of $MgBr_2$ = 184 x 0.03125 = 5.75 g

3 What mass of copper is formed when 2.00 g of copper(II) oxide reacts with 1.00 g of hydrogen? $CuO + H_2 \rightarrow Cu + H_2O$

Moles of CuO = $\frac{2.00}{79.5}$ = **0.0252 mol** **Moles of H_2** = $\frac{1.00}{2}$ = **0.500 mol**

0.0252 mol of CuO reacts with 0.0252 mol of H_2, ∴ H_2 is in excess; CuO is limiting reagent

moles of Cu formed = 0.0252 mol

mass of Cu = 63.5 x 0.0252 = 1.60 g

1) Calculate the concentration of the following solutions in mol/dm^3.

a) 0.10 moles of NaCl in 200 cm^3 $\frac{0.10}{\frac{200}{1000}}$ = **0.50 mol/dm^3**

b) 0.20 moles of H_2SO_4 in 100 cm^3 $\frac{0.20}{\frac{100}{1000}}$ = **2.0 mol/dm^3**

c) 0.020 moles of NaOH in 25 cm^3 $\frac{0.020}{\frac{25}{1000}}$ = **0.80 mol/dm^3**

2) Calculate the number of moles in the following solutions.

a) 100 cm^3 of 0.20 mol/dm^3 HNO_3 **0.20 x $\frac{100}{1000}$ = 0.020 mol**

b) 25 cm^3 of 1.50 mol/dm^3 KOH **1.50 x $\frac{25}{1000}$ = 0.0375 mol**

c) 50 cm^3 of 0.10 mol/dm^3 H_2SO_4 **0.10 x $\frac{50}{1000}$ = 0.0050 mol**

3) Calculate the concentration of the following solutions in g/dm^3.

a) 0.100 mol/dm^3 NaOH **0.100 x 40 = 4.0 g/dm^3**

b) 0.250 mol/dm^3 CH_3COOH **0.250 x 60 = 15 g/dm^3**

c) 1.50 mol/dm^3 HNO_3 **1.50 x 63 = 94.5 g/dm^3**

4) 0.20 moles of NaOH is dissolved in 250 cm^3 of water.

a) Calculate the concentration in mol/dm^3. $\frac{0.20}{\frac{250}{1000}}$ = **0.80 mol/dm^3**

b) Calculate the concentration in g/dm^3 **0.80 x 40 = 32 g/dm^3**

5) 5.0 g of KNO_3 is dissolved in 100 cm^3 of water.

a) Calculate the concentration in g/dm^3. $\frac{5.0}{\frac{100}{1000}}$ = **50 g/dm^3**

b) Calculate the concentration in mol/dm^3 $\frac{50}{101}$ = **0.495 mol/dm^3**

CALCULATIONS MIXTURE 1

1) Sodium reacts with oxygen as shown: $4Na + O_2 \rightarrow 2Na_2O$

Find the M_r of the following substances involved in this reaction.

a) sodium **Na** **23**

b) oxygen **O_2** **2(16) = 32**

c) sodium oxide **Na_2O** **2(23) + 16 = 62**

2) a) How many moles in the following:

i) 21.3 g of chlorine, Cl_2 $\frac{mass}{M_r} = \frac{21.3}{71} = 0.3$ mol

ii) 5.34 kg of aluminium bromide, $AlBr_3$ $\frac{mass}{M_r} = \frac{5340}{267} = 20$ mol

b) What is the mass of 0.25 moles of sulfur dioxide, SO_2? **M_r x moles = 64 x 0.25 = 16 g**

3) What mass of bromine reacts with 2.3 g of sodium to form sodium bromide? $2Na + Br_2 \rightarrow 2NaBr$

moles Na $= \frac{mass}{M_r} = \frac{2.3}{23} = 0.1$ mol

moles Br_2 $= \frac{0.1}{2} = 0.05$ mol

mass Br_2 = M_r x moles = 160 x 0.05 = 8.0 g

4) What mass of oxygen reacts with 280 g of iron to form iron oxide? $2Fe + 3O_2 \rightarrow 2Fe_2O_3$

moles Fe $= \frac{mass}{M_r} = \frac{280}{56} = 5$ mol

moles O_2 $= 5 \times \frac{3}{2} = 7.5$ mol

mass O_2 = M_r x moles = 32 x 7.5 = 240 g

5) What is the percentage atom economy to make tungsten (W) from tungsten oxide in this reaction? $WO_3 + 3H_2 \rightarrow W + 3H_2O$

	WO_3	+ $3H_2$	→	W	+ $3H_2O$
M_r	232	2		184	
Mass	232 g	3(2) g		184g	

% atom economy $= \frac{mass\ of\ desired\ product}{total\ mass\ of\ all\ reactants} \times 100 = \frac{184}{232+3(2)} \times 100 = 77.3\%$

6) a) What is the maximum mass of calcium hydroxide that can be formed by reaction of 2.8 g of calcium oxide with water?

$CaO + H_2O \rightarrow Ca(OH)_2$

moles CaO = $\frac{mass}{M_r}$ = $\frac{2.8}{56}$ = 0.05 mol

moles $Ca(OH)_2$ = 0.05 mol

mass $Ca(OH)_2$ = M_r x moles = 74 x 0.05 = 3.7 g

b) In a reaction, 2.6 g of calcium hydroxide was formed from 2.8 g of calcium oxide. Calculate the percentage yield.

% yield = $\frac{mass\ formed}{maximum\ mass\ possible}$ x 100 = $\frac{2.6}{3.7}$ x 100 = 70.3%

7) 1.95 g of potassium is reacted with 5.08 g of iodine. Work out which is the limiting reagent and then calculate the mass of potassium iodide formed.

$2K + I_2 \rightarrow 2KI$

moles K = $\frac{mass}{M_r}$ = $\frac{1.95}{39}$ = 0.05 mol

moles I_2 = $\frac{mass}{M_r}$ = $\frac{5.08}{254}$ = 0.02 mol

$2K + I_2 \rightarrow 2KI$

0.05 moles of K needs 0.025 moles of I_2 for all the K to react, but we don't have this much I_2

therefore I_2 is the limiting reagent (so the K is in excess and does not all react)

therefore only 0.04 moles of K reacts with the 0.02 moles of I_2, and forms 0.04 moles of KI

mass KI = M_r x moles = 166 x 0.04 = 6.64 g

8) 1.20 g of hydrated tin chloride decompose to form 1.01 g of anhydrous tin chloride on heating. Calculate the value of *x*.

$SnCl_2.xH_2O \rightarrow SnCl_2 + xH_2O$

moles $SnCl_2$ = $\frac{1.01}{190}$ = 0.005316 mol

mass H_2O = 1.20 – 1.01 = 0.19 g

moles H_2O = $\frac{0.19}{18}$ = 0.01056 mol

Ratio of moles $SnCl_2 : H_2O$ = 0.005316 : 0.01056 = $\frac{0.005316}{0.005316}$ $\frac{0.01056}{0.005316}$ = 1 : 2

∴ x = 2 (nearest whole number)

BOND ENERGY CALCULATIONS 2

Bond	N-N	C-C	C-O	N-H	C-H	H-H
Bond energy (kJ/mol)	158	348	360	388	412	436

Bond	O-H	O=O	C=C	C=O	N≡N
Bond energy (kJ/mol)	463	498	612	743	944

For each of the following reactions, use the bond energy data to:

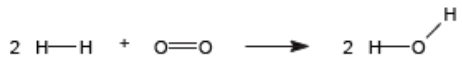
a) calculate the energy required to break the bonds in the reactants

b) calculate the energy released when the bonds in products are made

c) calculate the energy change for the reaction

d) state whether the reaction is exothermic or endothermic

1

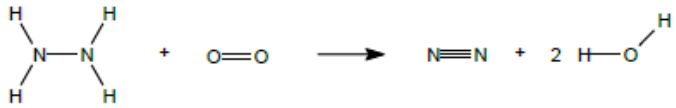


Break		Make		Energy change	= break – make	**Exothermic**
2 H-H	2(436)	4 O-H	4(463)		= 1370 – 1852	More energy released making bonds than needed to break bonds
O=O	498	Total	1852		= **–482 kJ/mol**	
Total	1370					

2

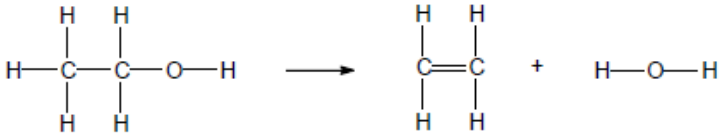
Break		Make		Energy change	= break – make	**Exothermic**
C=C	612	4 C=O	4(743)		= 3754 – 4824	More energy released making bonds than needed to break bonds
4 C-H	4(412)	4 O-H	4(463)		= **–1070 kJ/mol**	
3 O=O	3(498)	Total	4824			
Total	3754					

3



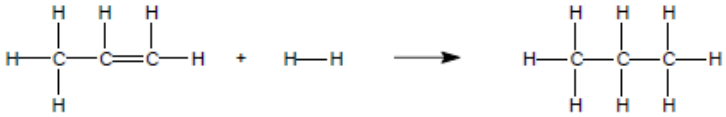
Break		Make		Energy change	= break – make	**Exothermic**
N-N	158	N≡N	944		= 2208 – 2796	More energy released making bonds than needed to break bonds
4 N-H	4(388)	4 O-H	4(463)		= –588 kJ/mol	
O=O	498	Total	2796			
Total	2208					

4



Break		Make		Energy change	= break – make	**Endothermic**
C-C	348	C=C	612		= 3231 – 3186	Less energy released making bonds than needed to break bonds
5 C-H	5(412)	4 C-H	4(412)		= **–+45 kJ/mol**	
C-O	360	2 O-H	2(463)			
O-H	463	Total	3186			
Total	3231					

5



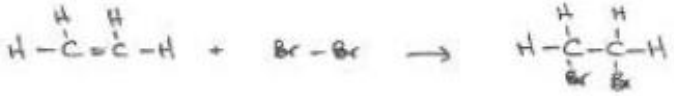
Break		Make		Energy change	= break – make	**Exothermic**
C=C	612	2 C-C	2(348)		= 3868 – 3992	More energy released making bonds than needed to break bonds
C-C	348	8 C-H	4(412)		= **–124 kJ/mol**	
6 C-H	6(412)	Total	3992			
H-H	436					
Total	3868					

① $H-H + Br-Br \rightarrow 2\ H-Br$

BREAK			MAKE		
	H–H	436		2 H–Br	2(366)
	Br–Br	193			732
		629			

Energy change = Break − Make
= 629 − 732
= −103 kJ/mol

Exothermic as more energy released making bonds than is needed to break bonds

② 

BREAK			MAKE		
	C=C	612		C–C	348
	4 C–H	4(412)		4 C–H	4(412)
	Br–Br	193		2 C–Br	2(276)
		2453			2548

Energy change = Break − Make
= 2453 − 2548
= −95 kJ/mol

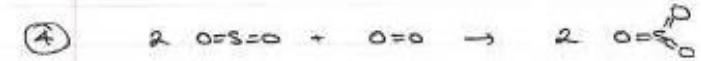
Exothermic as more energy released making bonds than is needed to break bonds

③ $H-H + Cl-Cl \rightarrow 2\ H-Cl$

BREAK			MAKE		
	H–H	436		2 H–Cl	2(431)
	Cl–Cl	242			862
		678			

Energy change = Break − Make
= 678 − 862
= −184 kJ/mol

Exothermic as more energy released making bonds than is needed to break bonds

④ 

BREAK			MAKE		
	4 S=O	4(431)		6 S=O	6(435)
	O=O	498			2610
		2238			

Energy change = Break − Make
= 2238 − 2610
= −372 kJ/mol

Exothermic as more energy released making bonds than is needed to break bonds

(5) 

Break	2 C–C	2(348)	Make	6 C=O	6(743)
	8 C–H	8(412)		8 O–H	8(463)
	5 O=O	5(498)			8162
		6482			

ΔH = Break − make = 6482 − 8162 = −1680 kJ/mol

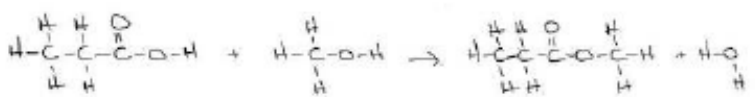
- Exothermic
- More energy released making bonds than needed to break bonds

(6) 

Break	C–C	348	Make	2 C–C	2(348)
	C=C	612		6 C–H	6(412)
	6 C–H	6(412)		2 C–Br	2(276)
	Br–Br	193		Total	3720
	Total	3625			

ΔH = Break − Make = 3625 − 3720 = −95 kJ/mol

- Exothermic
- More energy released making bonds than needed to break bonds

(7) 

Break	2 C–C	2(348)	Make	2 C–C	2(348)
	C=O	743		8 C–H	8(412)
	2 C–O	2(360)		C=O	743
	2 O–H	2(463)		2 C–O	2(360)
	8 C–H	8(412)		2 O–H	2(463)
	Total	6381		Total	6381

ΔH = break − make = 7307 − 7307 = 0 kJ/mol

- neither exothermic nor endothermic
- energy released making bonds equals energy needed to break bonds