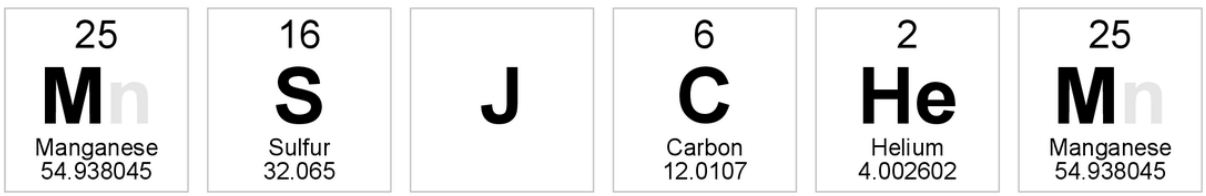
Stoichiometric Relationships Part one

IB CHEMISTRY SL/HL



Syllabus objectives:

Understandings:

- Atoms of different elements combine in fixed ratios to form compounds, which have different properties from their component elements.
- Mixtures contain more than one element and/or compound that are not chemically bonded together and so retain their individual properties.
- Mixtures are either homogeneous or heterogeneous.

Applications and skills:

- Deduction of chemical equations when reactants and products are specified.
- Application of the state symbols (s), (l), (g) and (aq) in equations.
- Explanation of observable changes in physical properties and temperature during changes of state.

Elements, compounds and mixtures

- All substances are made up of one or more elements.
- An element is a substance that cannot be broken down into a simpler substance by chemical means.
- All known elements are included on the periodic table which is shown below.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H 1.01						Atomic number Element Relative atomic mass											2 He 4.00
2	3 Li 6.94	4 Be 9.01											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
3	11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
4	19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.38	31 Ga 69.72	32 Ge 72.63	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.90
5	37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.96	43 Tc (98)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
6	55 Cs 132.91	56 Ba 137.33	57 † La 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.20	83 Bi 208.98	84 Po (209)	85 At (210)	86 Rn (222)
7	87 Fr (223)	88 Ra (226)	89 ‡ Ac (227)	104 Rf (267)	105 Db (268)	106 Sg (269)	107 Bh (270)	108 Hs (269)	109 Mt (278)	110 Ds (281)	111 Rg (281)	112 Cn (285)	113 Uut (286)	114 Uuq (289)	115 Uup (288)	116 Uuh (293)	117 Uus (294)	118 Uuo (294)

†	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.05	71 Lu 174.97
‡	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)

Compounds

- A compound is formed from two or more different elements chemically joined in a fixed ratio.
- Compounds have different properties from the elements that they are made from.

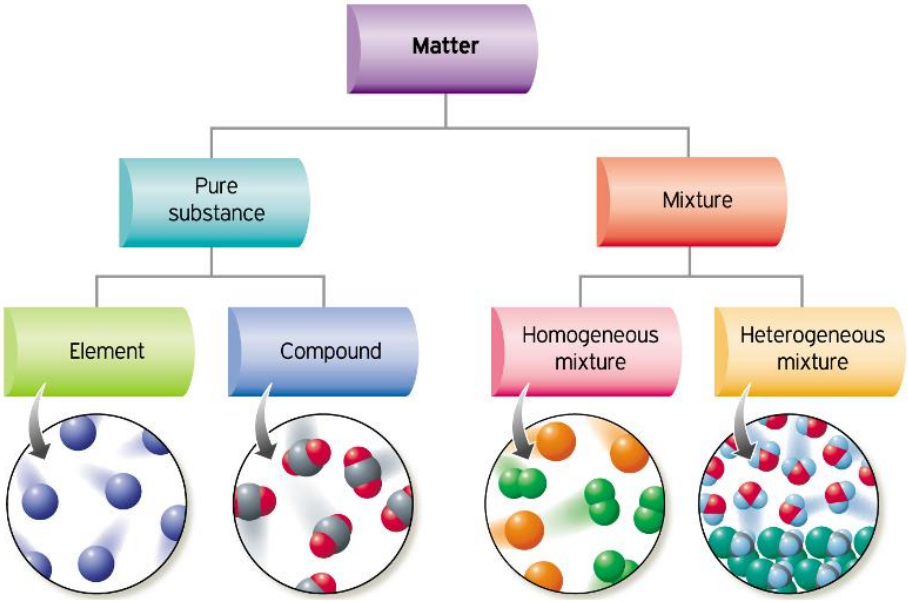
sodium + chlorine → sodium chloride

$$2Na_{(s)} + Cl_{2(g)} \rightarrow 2NaCl_{(s)}$$

- The properties of the compound above (NaCl) are different from the elements that it is made from.
- Sodium is a very reactive metal and chlorine is a poisonous gas. The product formed, NaCl, is safe for human consumption in small amounts.

Mixtures

- Mixtures contain more than one element and/or compound that are not chemically bonded together and so retain their individual properties.
- Mixtures can be either homogeneous or heterogeneous.
- A homogeneous mixture has the same uniform appearance and composition throughout (for example, a salt solution).
- A heterogeneous mixture consists of visibly different substances or phases (for example, sand and water).
- Matter can be divided into pure substances or mixtures, as can be seen in the flow chart below.



Exercises:

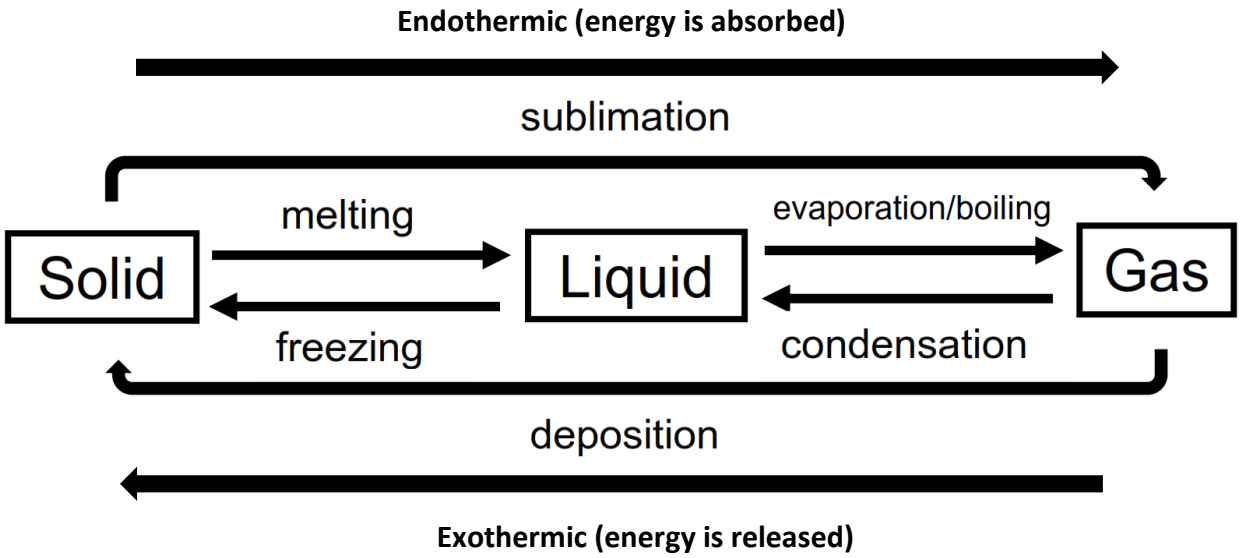
1. Distinguish between an element and compound.

2. Distinguish between a homogeneous and a heterogeneous mixture.

States of matter

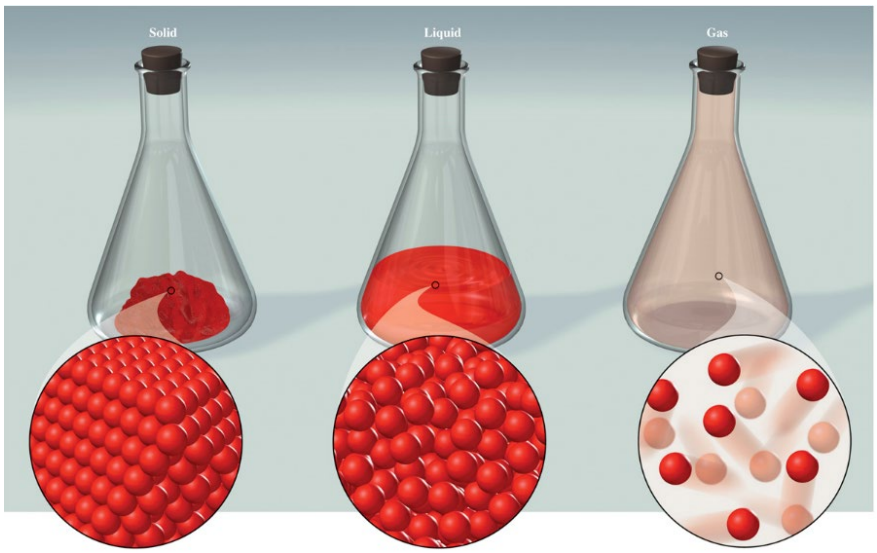
The changes of state are shown below.

- Melting is the change of state from a solid to a liquid.
- Freezing is the change of state from a liquid to a solid.
- Evaporating is the change of state form a liquid to a gas.
- Condensing is the change of state from a gas to a liquid.
- Sublimation is the change of state from a solid to a gas.
- Deposition is the change of state from a gas to a solid.



Particle models of solids, liquids and gases

- The particle models of a solid, liquid and gas are shown below.



Exercise: Complete the table to show the properties of the following states of matter.

Property	solid	liquid	gas
shape			
volume			
compressibility			
fluidity			

Physical and chemical changes

- In a physical change, no new substances are produced.
- The melting of ice is a physical change and can be represented by the following equation:

$$H_2O_{(s)} \rightarrow H_2O_{(l)}$$

- Evaporation of bromine:

$$Br_{2(l)} \rightarrow Br_{2(g)}$$

- Sublimation of iodine:

$$I_{2(s)} \rightarrow I_{2(g)}$$

- A chemical change results in the formation of new chemical substances.
- In a chemical reaction, the atoms in the reactants are rearranged to form new products.

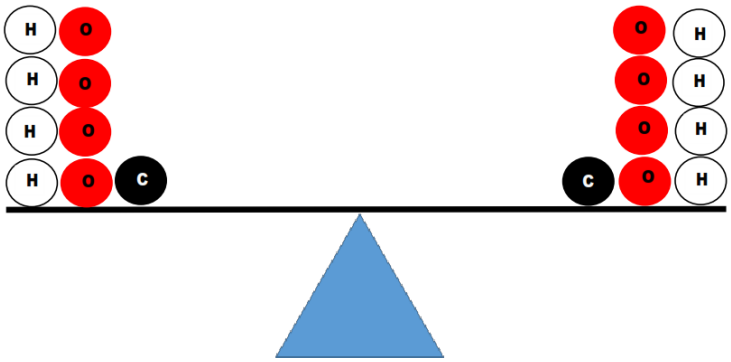
Example:

$$\mathbf{CH_{4(g)} + 2O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(l)}}$$

- The combustion of methane (shown in the equation above) is a chemical change as new chemical substances are formed (CO_2 and H_2O).

Balancing chemical equations

- The law of the conservation of mass states that mass (and therefore atoms) is conserved in a chemical reaction.
- Therefore, there must be the same number of each type of atom in the reactants and products, as shown in the diagram below.



$$CH_{4(g)} + 2O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(l)}$$

- To balance a chemical equation, we can only change the numbers in front of the reactants or products which are called coefficients.

Example 1:

- There is one Na atom in the reactants and one in the products. However, there are two Cl atoms in the reactants but only one in the products.

$$Na_{(s)} + Cl_{2(g)} \rightarrow NaCl_{(s)}$$

Na 1	Na 1
Cl 2	Cl 1

Write the balanced equation:

Example 2:

$$CaCO_{3(s)} + HCl_{(aq)} \rightarrow CaCl_{2(aq)} + H_2O_{(l)} + CO_{2(g)}$$

Write the balanced equation:

State symbols

- State symbols show the physical state (solid, liquid, gas or aqueous) of the reactants and products in a chemical equation.

  (s) – solid

  (l) – liquid

  (g) – gas

  (aq) – aqueous (in solution)

Example:

$$2Na_{(s)} + 2H_2O_{(l)} \rightarrow 2NaOH_{(aq)} + H_{2(g)}$$

Exercise:

Balance the following chemical equations using whole numbers. When each equation is balanced, calculate the sum of coefficients in the equations.

1. $CH_{4(g)} + O_{2(g)} \rightarrow CO_{2(g)} + H_2O_{(l)}$
2. $C_3H_{8(g)} + O_{2(g)} \rightarrow CO_{2(g)} + H_2O_{(l)}$
3. $CH_3OH_{(l)} + O_{2(g)} \rightarrow CO_{2(g)} + H_2O_{(l)}$
4. $Mg_{(s)} + HCl_{(aq)} \rightarrow MgCl_{2(aq)} + H_{2(g)}$
5. $CaCO_{3(s)} + HCl_{(aq)} \rightarrow CaCl_{2(aq)} + H_2O_{(l)} + CO_{2(g)}$
6. $NaCl_{(aq)} + CaO_{(aq)} \rightarrow CaCl_{2(aq)} + Na_2O_{(aq)}$
7. $Al_{(s)} + Fe_3O_{4(s)} \rightarrow Al_2O_{3(s)} + Fe_{(s)}$
8. $Mg_3N_{2(s)} + H_2SO_{4(aq)} \rightarrow MgSO_{4(aq)} + (NH_4)_2SO_{4(aq)}$
9. $Fe_2O_{3(s)} + C_{(s)} \rightarrow Fe_{(s)} + CO_{(g)}$
10. $Al(OH)_{3(s)} + H_2SO_{4(aq)} \rightarrow Al_2(SO_4)_{3(aq)} + H_2O_{(l)}$