EMPIRICAL FORMULA

4.8.1

Quantities of chemicals, expressed in moles, can be used to find the formula of a compound, to establish an equation and to determine reacting masses.

(a) A compound contains 72% magnesium and 28% nitrogen. What is its empirical formula?

....

....

....

.... [2]

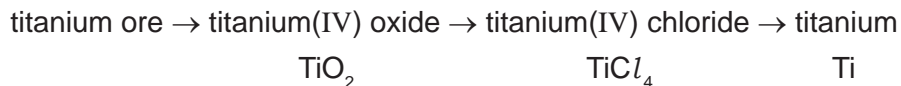(a) $72/24 = 3$ and $28/14 = 2$ [1]
Mg_3N_2 [1]
accept just formula for [2] even with incorrect or no working
NOT ecf

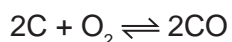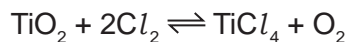## 4.8.2

Titanium is a transition element. It is isolated by the following reactions.

titanium ore → titanium(IV) oxide → titanium(IV) chloride → titanium

$$TiO_2 \qquad\qquad TiCl_4 \qquad\qquad Ti$$

(a) Why is it usually necessary to include a number in the name of the compounds of transition elements?

.... [1]

Titanium(IV) chloride is made by heating the oxide with coke and chlorine.

$$TiO_2 + 2Cl_2 \rightleftharpoons TiCl_4 + O_2$$

$$2C + O_2 \rightleftharpoons 2CO$$

(b) The titanium ore contains 36.8% iron, 31.6% titanium and the remainder is oxygen.

    (i) Determine the percentage of oxygen in this titanium compound.

    percentage of oxygen = ... %   [1]

    (ii) Calculate the number of moles of atoms for each element.
The number of moles of Fe is shown as an example.
number of moles of Fe = 36.8 / 56 = 0.66

    number of moles of Ti   = ...

    number of moles of O   = ... [1]

    (iii) What is the simplest ratio for the moles of atoms?

$$\text{Fe} \quad : \quad \text{Ti} \quad : \quad \text{O}$$

    ....

    [1]

    (iv) What is the formula of this titanium compound?

    .... [1]

(a) a transition element has more than one oxidation state or valency [1]
accept different oxidation states

(b) **(i)** percentage of oxygen = 31.6% [1]

(ii) calculate the number of moles of atoms for each element

number of moles of Ti = 31.6/48 = 0.66

number of moles of O = 31.6/16 = 1.98 **accept** 2 [1]
both correct for one mark

(iii) the simplest <u>whole number ratio</u> for moles of atoms:

Fe : Ti : O
1   1   3 [1]

(iv) formula is $FeTiO_3$ **accept** $TiFeO_3$ [1]
must be whole numbers from **(iii)** or cancelled numbers from **(iii)**
mark **ecf** throughout

4.8.3

An ore of copper is the mineral, chalcopyrite. This is a mixed sulphide of iron and copper.

(a) Analysis of a sample of this ore shows that 13.80 g of the ore contained 4.80 g of copper, 4.20 g of iron and the rest sulphur.
Complete the table and calculate the empirical formula of chalcopyrite.

	copper	iron	sulphur
composition by mass / g	4.80	4.20	
number of moles of atoms			
simplest mole ratio of atoms			

[3]

The empirical formula is

.... [1]

(a)

	copper	iron	sulphur	
composition by mass/g	(4.80)	(4.20)	4.8	[1]
number of moles of atoms	0.075	0.075	0.15	[1]
simplest mole ratio of atoms	1	1	2	[1]

[3]

The empirical formula is $CuFeS_2$ [1]

4.8.4

Across the world, food safety agencies are investigating the presence of minute traces of the toxic hydrocarbon, benzene, in soft drinks. It is formed by the reduction of sodium benzoate by vitamin C.
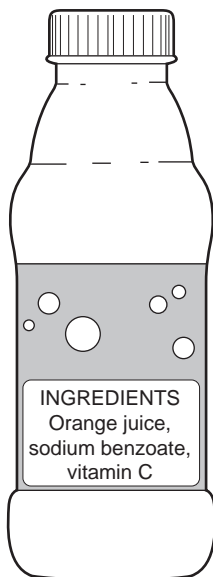
Benzene contains 92.3% of carbon and its relative molecular mass is 78.

(i) What is the percentage of hydrogen in benzene?

.... [1]

(ii) Calculate the ratio of moles of C atoms : moles of H atoms in benzene.

....

.... [2]

(iii) Calculate its empirical formula and **then** its molecular formula.

The empirical formula of benzene is   ....

The molecular formula of benzene is   ....   [2]

(i) 7.7% [1]

(ii) for any number: equal number ratio [2]
for example 1:1 **or** 6:6

(iii) empirical formula is CH [1]
molecular formula is C_6H_6 [1]
no e.c.f., award of marks not dependent on **(ii)**

4.8.5

Maleic acid is an unsaturated acid. 5.8 g of this acid contained 2.4 g of carbon, 0.2 g of hydrogen and 3.2 g of oxygen.

(i) How do you know that the acid contained only carbon, hydrogen and oxygen?

....

.... [1]

(ii) Calculate the empirical formula of maleic acid.

Number of moles of carbon atoms = ...

Number of moles of hydrogen atoms = ...

Number of moles of oxygen atoms = ...

The empirical formula is .... [3]

(iii) The mass of one mole of maleic acid is 116 g. What is its molecular formula?

.... [2]

(iv) Maleic acid is dibasic. One mole of acid produces two moles of H^+. Deduce its structural formula.

(i) add up to 5.8 g   [1]

(ii) moles of C atoms = 2.4/12 = 0.2
   moles of H atoms = 0.2/1 = 0.2
   moles of O atoms = 3.2/16 = 0.2
   all three correct = 2   [2]
   two correct = 1
   empirical formula CHO   [1]

(iii) 116/29 = 4   [1]
   $C_4H_4O_4$ [1]
   correct formula with no working scores both marks.

(iv) HOOCCH=CHCOOH / $CH_2=C(COOH)_2$ [2]

4.8.6

Compound X is a colourless liquid at room temperature.

Compound X is a hydrocarbon. It contains 85.7% of carbon. The mass of one mole of X is 84 g.

(i) What is the percentage of hydrogen in the compound ?

.... [1]

(ii) Calculate the empirical formula of X. Show your working.

empirical formula = ... [3]

(iii) What is the molecular formula of compound X?

.... [1]

(i) 14.3 [1]

(ii) $85.7 \div 12$ and $14.3 \div 1$ **or** 7.14 and 14.3 [1]
ratio 1:2 [1]
CH_2 [1]
note: Award all 3 marks for correct answer
allow: alternative working e.g.
$85.7 \times 84 \div 100$ and $14.3 \times 84 \div 100$ **or** 71.988/72 and 12/12.012 [1]
6:12 **or** ratio 1:2 [1]
CH_2 [1]

(iii) C_6H_{12} [1]

4.8.7

(a) A compound **X** contains 82.76% of carbon by mass and 17.24% of hydrogen by mass.

(i) Calculate the empirical formula of compound **X**.

[2]

(ii) Compound **X** has a relative molecular mass of 58.

Deduce the molecular formula of compound **X**.

[2]

(a) (i) 82.76/12 and 17.2(4)(/1)

or evaluation: 6.89 / 6.9(0) and 17.2(4)   [1]

C_2H_5 [1]

OR

82.76 / 100 × 58 = 48 and 17.24 / 100 × 58 = 10

or evaluation i.e. 48 and 10   [1]

C_2H_5 [1]

(ii) $(C_2H_5 =)$ 29   [1]

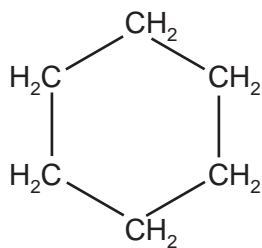(58 / 29 = 2) C_4H_{10} [1]

OR:

82.76 / 100 × 58 = 48 and 17.24 / 100 × 58 = 10

or evaluation i.e. 48 and 10   [1]

48 / 12 = 4 10 / 1 = 10 (therefore) C_4H_{10} [1]

4.8.8

The structural formula of cyclohexane is drawn below.

(a) What are the molecular and empirical formulae of cyclohexane?

molecular formula ....

empirical formula ....   [2]

molecular formula C_6H_{12} [1]
empirical formula CH_2 [1]

4.8.9

Maleic acid is an unsaturated acid. 5.8 g of this acid contained 2.4 g of carbon, 0.2 g of hydrogen and 3.2 g of oxygen.

(i) How do you know that the acid contained only carbon, hydrogen and oxygen?

....

.... [1]

(ii) Calculate the empirical formula of maleic acid.

Number of moles of carbon atoms = ...

Number of moles of hydrogen atoms = ...

Number of moles of oxygen atoms = ...

The empirical formula is .... [3]

(i) add up to 5.8 g   [1]

(ii) moles of C atoms = 2.4/12 = 0.2
      moles of H atoms = 0.2/1 = 0.2
      moles of O atoms = 3.2/16 = 0.2
      all three correct = 2   [2]
      two correct = 1
      empirical formula CHO   [1]

4.8.10

(a) A compound, **X**, contains 55.85% carbon, 6.97% hydrogen and 37.18% oxygen.

(i) How does this prove that compound **X** contains only carbon, hydrogen and oxygen?

.... [1]

(ii) Use the above percentages to calculate the empirical formula of compound **X**.

.... [2]

(iii) The M_r of **X** is 86.

What is its molecular formula?

.... [2]

(a)(i)	adds up to 100%;
(a)(ii)	**M1** 55.85/12 **and** 6.97(/1) **and** 37.2/16; **or** evaluation 4.650 6.970 2.325; **M2** C_2H_3O; correct answer with no working = [2]
(a)(iii)	**M1** (86/)43; **M2** $C_4H_6O_2$; correct answer with no working = [2]