**Empirical and Molecular Formulae**

**1** Find the empirical formulae of the substances with the following percentage composition

(a) 80% copper and 20% oxygen

(b) 53% aluminium and 47% oxygen

(c) 1·6% hydrogen, 22·2% nitrogen and 76·2% oxygen

**2** Calculate the empirical formula of the oxide of sulfur which is 40% sulfur by mass.

**3** A hydrocarbon contains 90% carbon. Calculate the empirical formula of the hydrocarbon.

**4** An oxide of silicon was produced from 0·28 g of silicon. The mass of the oxide was 0·60 g. Calculate the empirical formula of the oxide.

**5** 10·2 g of vanadium is combined with 21·3 g of chlorine to make vanadium chloride. Calculate the empirical formula of the vanadium chloride.

**6** The empirical formula of a substance is CH2. Its molar mass is 84 g mol−1. Find the molecular formula of the substance.

**7** Analysis gave the following data for three unknown substances

(a) 85·7% C and 14·3% H; *M* = 28 g mol−1

(b) 30·4% N and 69·6% O; *M* = 92 g mol−1

(c) 2% H, 33% S and 65% O; *M* = 98 g mol−1

Find the molecular formulae for each of the substances

**8** A hydrocarbon contains 82·7% carbon and 17·3% hydrogen by mass

(a) What is the empirical formula of the hydrocarbon?

(b) Given that the molar mass of the hydrocarbon is 58 g mol−1, what is its molecular formula?

**9** A gaseous hydrocarbon was found to contain 80% carbon and 20% hydrogen by mass

(a) Calculate the empirical formula of the hydrocarbon

(b) The hydrocarbon was found to have a molar mass of 30 g mol−1. Use this value to work out the molecular formula of the hydrocarbon.

**10** (a) An oxide of nitrogen contains 30·3% nitrogen. Calculate the empirical formula of the oxide.

(b) If the molar mass of the oxide is 92 g mol−1, use your answer in (a) to determine the molecular formula of the oxide.

**11** (a) Vitamin C has a mass composition of 40·92% carbon, 4·58% hydrogen and 54·40% oxygen. Calculate the empirical formula of Vitamin C.

(b) If the molar mass of Vitamin C is 176 g mol−1, use your answer in (a) to determine the molecular formula for Vitamin C.

**12** (a) An organic compound has a mass composition if 26·67% carbon, 2·22% hydrogen and 71·11% oxygen. Calculate the empirical formula of the compound.

(b) If the molar mass of the compound is 90 g mol−1, use your answer in (a) to determine the molecular formula of the compound.

**13** A lead sulfide compound was made by heating 2·95 g of lead with excess sulfur. Once all the lead had reacted, the excess sulfur was burnt off. The mass of the final product was 3·42 g.

*M*(Pb) = 207 g mol−1, *M*(S) = 32·1 g mol−1

(a) Calculate the moles of lead used.

(b) Calculate to mass and hence the moles of sulfur reacted.

(c) Calculate the empirical formula of the compound.

Activity 7E: **Percentage Composition, Empirical and Molecular Formulae Answers**

**1**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **(a)** |  |  | copper | oxygen |
|  |  | % | 80 | 20 |
|  |  | *M* | 63·5 | 16·0 |
|  |  | *n* | 1·26 | 1·25 |
|  |  | ÷ smallest | 1·25  : | 1·25 |
|  |  | simplest ratio | 1 | 1 |

empirical formula: CuO

|  |  |  |  |
| --- | --- | --- | --- |
| (b) |  | aluminium | oxygen |
|  | % | 53 | 47 |
|  | *M* | 27·0 | 16·0 |
|  | *n* | 1·96 | 2·94 |
|  | ÷ smallest | 1·96 | 1·96 |
|  | × 2 | 1  : | 1·50 |
|  | simplest ratio | 2 | 3 |

empirical formula: Al2O3

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| (c) |  | hydrogen | nitrogen | oxygen |
|  | % | 1·6 | 22·2 | 76·2 |
|  | *M* | 1·0 | 14·0 | 16·0 |
|  | *n* | 1·6 | 1·59 | 4·76 |
|  | ÷ smallest | 1·59  : | 1·59  : | 1·59 |
|  | simplest ratio | 1 | 1 | 3 |

empirical formula: HNO3

|  |  |  |  |
| --- | --- | --- | --- |
| **2** |  | sulfur | oxygen |
|  | % | 40 | 60 |
|  | *M* | 32·1 | 16·0 |
|  | *n* | 1·25 | 3·75 |
|  | ÷ smallest | 1·25  : | 1·25 |
|  | simplest ratio | 1 | 3 |

empirical formula: SO3

|  |  |  |  |
| --- | --- | --- | --- |
| **3** |  | carbon | hydrogen |
|  | % | 90 | 10 |
|  | *M* | 12·0 | 1·0 |
|  | *n* | 7·5 | 10 |
|  | ÷ smallest | 7·5 | 7·5 |
|  | × 3 | 1  : | 1·33 (1⅓) |
|  | simplest ratio | 3 | 4 |

empirical formula: C3H4

|  |  |  |  |
| --- | --- | --- | --- |
| **4** |  | silicon | oxygen |
|  | *m* | 0·28 | 0·60 − 0·28 |
|  | *M* | 28·1 | 16·0 |
|  | *n* | 9·96 × 10−3 | 0·0200 |
|  | ÷ smallest | 9·96 × 10−3  : | 9·96 × 10−3 |
|  | simplest ratio | 1 | 2 |

empirical formula: SiO2

|  |  |  |  |
| --- | --- | --- | --- |
| **5** |  | vanadium | chlorine |
|  | *m* | 10·2 | 21·3 |
|  | *M* | 50·9 | 35·5 |
|  | *n* | 0·200 | 0·600 |
|  | ÷ smallest | 0·200  : | 0·200 |
|  | simplest ratio | 1 | 3 |

empirical formula: VCl3

**6** molecular formula = =  = 6CH2 = C6H12

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **7** | (a) |  | carbon | hydrogen |
|  |  | % | 85·7 | 14·3 |
|  |  | *M* | 12·0 | 1·0 |
|  |  | *n* | 7·14 | 14·3 |
|  |  | ÷ smallest | 7·14  : | 7·14 |
|  |  | simplest ratio | 1 | 2 |

empirical formula: CH2

molecular formula =  = 2 × CH2 = C2H4

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **7** | (b) |  | nitrogen | oxygen |
|  |  | % | 30·4 | 69·6 |
|  |  | *M* | 14·0 | 16·0 |
|  |  | *n* | 2·17 | 4·35 |
|  |  | ÷ smallest | 2·17  : | 2·17 |
|  |  | simplest ratio | 1 | 2 |

empirical formula: NO2

molecular formula =  = 2 × NO2 = N2O4

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | (c) |  | hydrogen | sulfur | oxygen |
|  |  | % | 2 | 33 | 65 |
|  |  | *M* | 1·0 | 32·1 | 16·0 |
|  |  | *n* | 2 | 1·03 | 4·06 |
|  |  | ÷ smallest | 1·03  : | 1·03  : | 1·03 |
|  |  | simplest ratio | 2 | 1 | 4 |

empirical formula: H2SO4

molecular formula =  = 1 × H2SO4 = H2SO4

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **8** | (a) |  | carbon | hydrogen |
|  |  | % | 82·7 | 17·3 |
|  |  | *M* | 12·0 | 1·0 |
|  |  | *n* | 6·89 | 17·3 |
|  |  | ÷ smallest | 6·89 | 6·89 |
|  |  | × 2 | 1  : | 2·51 |
|  |  | simplest ratio | 2 | 5 |

empirical formula: C2H5

(b) molecular formula =  = 2 × C2H5 = C4H10

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **9** | (a) |  | carbon | hydrogen |
|  |  | % | 80 | 20 |
|  |  | *M* | 12·0 | 1·0 |
|  |  | *n* | 6·67 | 20 |
|  |  | ÷ smallest | 6·67  : | 6·67 |
|  |  | simplest ratio | 1 | 3 |

empirical formula: CH3

(b) molecular formula =  = 2 × CH3 = C2H6

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **10** | (a) |  | nitrogen | oxygen |
|  |  | % | 30·3 | 69·7 |
|  |  | *M* | 14·0 | 16·0 |
|  |  | *n* | 2·16 | 4·36 |
|  |  | ÷ smallest | 2·16  : | 2·16 |
|  |  | simplest ratio | 1 | 2 |

empirical formula: NO2

(b) molecular formula =  = 2 × NO2 = N2O4

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **11** | (a) |  | carbon | hydrogen | oxygen |
|  |  | % | 40·92 | 4·58 | 54·50 |
|  |  | *M* | 12·0 | 1·0 | 16·0 |
|  |  | *n* | 3·41 | 4·58 | 3·41 |
|  |  | ÷ smallest | 3·41 | 3·41 | 3·41 |
|  |  | × 3 | 1  : | 1·34 (1⅓)  : | 1 |
|  |  | simplest ratio | 3 | 4 | 3 |

empirical formula: C3H4O3

(b) molecular formula =  = 2 × C3H4O3 = C6H8O6

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **12** | (a) |  | carbon | hydrogen | oxygen |
|  |  | % | 26·67 | 2·22 | 71·11 |
|  |  | *M* | 12·0 | 1·0 | 16·0 |
|  |  | *n* | 2·22 | 2·22 | 4·44 |
|  |  | ÷ smallest | 2·22  : | 2·22  : | 2·22 |
|  |  | simplest ratio | 1 | 1 | 2 |

empirical formula: CHO2

(b) molecular formula =  = 2 × CHO2 = C2H2O4

**13** (a) *n*(Pb) =  =  = 0·01425 mol

(b) *m*(S) = *m*(lead sulfide) – *m*(lead) = 3·42 − 2·95 = 0·47 g

*n*(S) =  =  = 0·0146 mol

(c)  =  = , i.e. empirical formula is PbS