### Problem set 3.3 Molecular formulae

The empirical formula that we have been working with is not always the chemical formula for the molecule in question. For instance, dinitrogen tetroxide (N₂O₄) would have an empirical formula of NO₂ because this is the simplest ratio of these atoms. The molecular mass of these two is different, however, as the mass of one mole of N₂O₄ is (2x14.006)+(4x15.9994) = 92.0096 g/mole and the mass of one mole of NO₂ is half of that, 46.0048 g/mole. If an indication of the molar mass can be found, one can work out the molecular formula from the empirical formula.

For example, the percent composition of a hydrocarbon is 85.63% carbon and 14.37% hydrogen. 0.015 moles of the substance has a mass of 0.4208 grams. What is its molecular formula?

Moles of Carbon = (85.63 grams)/(12.011 g/mole) = 7.13 moles  
Moles of Hydrogen = (14.37 grams)/(1.0079 g/mole) = 14.26 moles

so the empirical formula is CH₂. The mass of one mole of molecules is 0.4208 grams/0.015 moles = 28.05 grams/mole

The molecular formula will always be some multiple of the empirical formula. In this case the mass of a CH₂ unit is 12.011+2(1.0079) = 14.027 grams/mole

so x(14.027) = 28.05

x = 2

The molecular formula, then, is 2X the empirical formula so the molecular formula would be C₂H₄.

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#### 3.1 A compound has an empirical formula of CH₂O.

a) Suggest 3 molecules that would have this as an empirical formula  
b) 3.5 moles of this compound has a mass of 630 grams. What is the molecular formula of this compound?

#### 3.2 A gas has an empirical formula of CH₂. A metal container is filled with the gas and found to weigh 1.75 times as much as the same container filled with oxygen gas at the same temperature and pressure. What is the molecular formula of the gas?

#### 3.3 A compound is 7.7% hydrogen and 92.3% carbon. It has a molar mass of 78 g/mole. What is the molecular formula of the compound?

#### 3.4 Mannose is a sugar which has a molecular mass of 180 g/mole, and contains only carbon, hydrogen and oxygen. A 2.36 g sample of mannose was analysed and found to contain 0.994 g of carbon, 0.158 g hydrogen and the rest oxygen. Calculate the molecular formula for the compound.

#### 3.5 4.75 grams of uranium combined with exactly 2.28 grams of fluorine to produce 0.0200 moles of a gaseous compound. What is the molar mass, empirical formula, molecular formula, and name of this compound?

#### 3.6 A gaseous compound was found to contain 65.4% carbon, 9.15% hydrogen, and 25.4% nitrogen. By comparing the masses of equal volumes of oxygen and this compound under the same conditions of temperature and pressure, it was found that the mass of this compound was 6.875 times greater than oxygen. Calculate the molar mass, empirical formula, and molecular formula of this compound.

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**Answers:**

3.1  
a) C₃H₄O₂, C₄H₆O₃, C₄H₆O₄ others are possible  
b) 180 g/mole which is 6 times the empirical mass, so C₆H₁₂O₆.

3.2  
molecular mass is 4 times empirical, so C₄H₆ is molecular formula

3.3  
C₄H₆

3.4  
C₄H₁₂O₆

3.5  
molar mass is 351.5 g/mole, Empirical formula UF₆, molecular formula UF₆, name Uranium fluoride. (or Uranium hexafluoride)

3.6  
molar mass: 220 g/mole, empirical formula: C₃H₆N, molecular formula, C₁₂H₂₀N₄.