University of Melbourne

Department of Chemical Engineering

CHEN20010 MATERIAL AND ENERGY BALANCES

EXERCISE SHEET A

COMPOSITIONS OF MIXTURES

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1. An aqueous mixture of sulphuric acid and nitric acid has a composition on a weight basis of 37.3 % H_2SO_4, 14.4 % HNO_3 with the balance water. Express the composition on a molar basis. What is the average molecular weight of the solution?

MW (H_2SO_4) = 98.1 MW (HNO_3) = 63.0 MW (H_2O) = 18.02

2. A mixture contains 61.3% w/w methanol, 12.4 % $^w/_w$ ethanol, 9.3% $^w/_w$ 1-propanol, 10.7% $^w/_w$ 2-propanol and the balance water. Determine the composition on a molar basis expressing the answer in mol %. What is the average molecular weight of the mixture?

		MW
methanol	CH_3OH	32.04
ethanol	C_2H_5OH	46.07
1-propanol	C_3H_7OH	60.10
2-propanol	C_3H_7OH	60.10
water	H_2O	18.02

3. A gaseous mixture contains methanol, hydrogen, carbon dioxide and carbon monoxide. The partial pressure of methanol is 129.3 kPa, for hydrogen is 2164 kPa and for carbon dioxide is 1581 kPa. The total pressure of the mixture is 4681 kPa. Express the composition of the mixture on a molar basis in mol %.

4. A gaseous mixture contains 32.9 mol % He, 40.7 mol % N_2 and 26.4 mol % Ar. What is the composition of this mixture on a mass basis?

MW (He) = 4.003 MW (N_2) = 28.02 MW (Ar) = 39.95

5. Martian atmosphere is predominantly carbon dioxide with small amounts of other compounds. The composition is 93.82 mol % CO_2, 4.17 mol % N_2, 1.73 mol % Ar, 0.18 mol % O_2 and 0.10 mol % CO. What is the average molecular weight of the gas? At a point on the surface of Mars away from the mountain regions the atmospheric pressure is 600 Pa. What is the partial pressure of N_2 at that point?

MW (CO_2) = 44.01 MW (N_2) = 28.01 MW (Ar) = 39.95

MW (O_2) = 32.00 MW (CO) = 28.01

6. The composition of natural gas varies significantly depending on its source. Consider a natural gas with a composition on a molar basis as 80.0 % methane, 3.0 % ethane, 0.50 % propane, 14.0 % nitrogen and 2.5 % carbon dioxide. What is the average molecular weight of this gas? What is the composition of the gas expressed in % $^{w}/_{w}$?

MW (CH_4) = 16.04 MW (C_2H_6) = 30.07 MW (C_3H_8) = 44.10
MW (N_2) = 28.01 MW (CO_2) = 44.01

7. The composition of stack gases after combustion of a sample of fuel is 74.5 mol % N_2, 1.9 mol % O_2, 15.2 mol % CO_2, 3.9 mol % CO and balance H_2O. Express this composition on a dry, mass basis.

MW (N_2) = 28.01 MW (O_2) = 32.00 MW (CO_2) = 44.01
MW (CO) = 28.01 MW (H_2O) = 18.02

8. 3.764 g of cobalt chloride and 1.090 g of manganese chloride are dissolved completely into 250.00 g of water. What is the composition of the prepared solution on a molar basis?

MW ($CoCl_2$) = 129.8 MW ($MnCl_2$) = 125.9 MW (H_2O) = 18.02

9. A two-component hydrocarbon mixture contains propanoic acid and another unidentified component. The mass fraction of propanoic acid is 0.387 while its mole fraction is 0.317. The molecular weight of propanoic acid is 60.05. What is the molecular weight of the other unidentified component?

10. A binary mixture of methyl mercaptan and n-butyl mercaptan has an average molecular weight of 84.53. What is the mass fraction of methyl mercaptan in the mixture?

		MW
methyl mercaptan	CH_3SH	48.11
n-butyl mercaptan	C_4H_9SH	90.19

11. A mixture of aromatic hydrocarbons contains benzene, toluene, xylene, cumene and naphthalene. It is known that the mixture contains 34.0 mol % benzene, 17.5 mol % toluene and 19.8 mol % xylene. The mole fractions of cumene and naphthalene are unknown, but it is known that the mass fraction of naphthalene is 0.302. What is the composition of the mixture on a weight basis?

MW (benzene) = 78.1 MW (toluene) = 92.1
MW (xylene) = 106.2 MW (cumene) = 120.2
MW (naphthalene) = 128.2

12. A flask contains 4.21 L of an iso-propanol-water mixture at 20°C containing 72.0 % $^{w}/_{w}$ of iso-propanol. The density of such a mixture is 0.8588 kg/L.

a) Calculate the amount of pure iso-propanol (C_3H_7OH) contained in the flask expressed as:
   i. kg
   ii. mol

b) Calculate the propanol concentration expressed as:
   i. g/L
   ii. mol fraction
   iii. molarity
   iv. mole ratio
   v. mass ratio

MW(iso-propanol) = 60.1 MW(water) = 18.0

13. A mixture contains methanol, ethanol, propanol and water. It is known that

a) The average molecular weight of the mixture is 32.11.
b) The mole fraction of CH_3OH on a water-free basis is 0.188.
c) 1.70 moles of C_2H_5OH are present for every mole of C_3H_7OH.

Calculate the composition of the mixture on a molar basis. The molecular weights of the relevant compounds are:

MW(CH_3OH) = 32.04 MW(C_2H_5OH) = 46.07
MW(C_3H_7OH) = 60.09 MW(H_2O) = 18.02

14. 100 mL of a formic acid-water mixture containing 70 % $^{w}/_{w}$ of formic acid is added to a flask containing 250 mL of an formic acid-water mixture containing 12 % $^{w}/_{w}$ of the acid, both at 20°C. The densities of the 12 % $^{w}/_{w}$ and 70 % $^{w}/_{w}$ mixtures are 1.0351 kg/L and 1.1531 kg/L respectively. The molecular weight of formic acid is 46.0. Calculate:

a) the number of moles of pure formic acid in the flask after mixing
b) the mass fraction of formic acid after mixing.

15. A sample taken from a reactor contains formic acid, HCOOH, acetic acid, CH_3COOH, propanoic acid, C_2H_5COOH, hydrogen, H_2, and carbon monoxide, CO. It is known that the mixture contains 11.91 % $^{w}/_{w}$ HCOOH and 23.71 % $^{w}/_{w}$ CH_3COOH but the mass fractions of the remaining components are unknown. It is known however that the mole fractions of H_2 and CO are 0.0908 and 0.4219 respectively. Calculate the composition of the mixture on a molar basis, and determine the average molecular weight.

MW (HCOOH) = 46.03 MW (H_2) = 2.02
MW (CH_3COOH) = 60.05 MW (CO) = 28.01
MW (C_2H_5COOH) = 74.08

16. A batch of a mixed solvent has been prepared in a blending plant from three pure liquids: acetone, nitrobenzene and glycerol. The batch was despatched to a customer before all the mass and analytical information were recorded and the only information available from the plant and laboratory is:

i. 24 L of nitrobenzene was used
ii. the batch of mixed solvent contains 33 % w/w of glycerol
iii. the batch of mixed solvent contains 1.3 mole of acetone per mole of glycerol.

Calculate:

a) Total mass of the batch (kg)
b) Total volume of the batch (L)
c) Analysis of the batch, % $^{w}/_{w}$
d) Analysis of the batch, mol %

It may be assumed that the compounds are completely miscible and that there is no volume change on mixing.

Data:	Mol. Wt.	Density (kg/L)
Acetone	58.08	0.792
Glycerol	92.09	0.998
Nitrobenzene	123.11	1.205

MATLAB EXERCISES – Use MATLAB to answer this problem

M17. Iodomethane, CH_3I, may be prepared by the reaction of methanol with hydrogen iodide by the reaction,

$$CH_3OH + HI \rightarrow CH_3I + H_2O$$

The effluent stream leaving an iodomethane reactor has a composition of 3.9 % mol CH_3OH, 20.5 % mol HI, 37.8 % $^{w}/_{w}$ CH_3I with the balance H_2O. What is the average molecular weight of the mixture? Also, express the composition on a weight basis.

MW (CH_3OH) = 32.04 g/mol MW (HI) = 127.90 g/mol

MW (CH_3I) = 141.94 g/mol MW (H_2O) = 18.02 g/mol