CHE1031 Practice set 3: Composition of substances & solutions - KEY

These are optional practice problems. It's up to you how to solve them and they don't need to be completed or passed in. As the answer key is posted with this problem set, you may find them useful in 'reverse engineering' HW problems or in studying for quizzes and exams.
Note that answers to quantitative problems are provided in blue.

3.1: Formula mass and the mole concept

1. What is the total mass of hydrogen in each of the molecules?

(a) CH_4
(b) $CHCl_3$
(c) $C_{12}H_{10}O_6$
(d) $CH_3CH_2CH_2CH_2CH_3$
(a) (4)(1.01 amu) = 4.04 amu
(b) 1.01 amu
(c) (10)(1.01 amu) = 10.10 amu
(d) (12)(1.01 amu) = 12.12 amu

2. Write a sentence that describes how to determine the number of moles of a compound in a known mass of the compound if we know its molecular formula.
Molar mass (aka molecular weight; g/mol) can be calculated from molecular formula. MW can be used to convert mass (g) to moles by unit conversion.

3. Calculate the molar mass of each of the following:

(a) the anesthetic halothane, $C_2HBrClF_3$
(b) the herbicide paraquat, $C_{12}H_{14}N_2Cl_2$
(c) caffeine, $C_8H_{10}N_4O_2$
(d) urea, $CO(NH_2)_2$
(e) a typical soap, $C_{17}H_{35}CO_2Na$
(a) 197.35 g/mol
(b) 257.18 g/mol
(c) 194.20 g/mol
(d) 60.06 g/mol
(e) 306.50 g/mol

4. Determine the number of moles of compound and the number of moles of each type of atom in each of the following:
(a) 25 lb of the herbicide Treflan, $C_{13}H_{16}N_2O_4F$ (1 lb = 454 g)
(b) 0.125 kg of the insecticide Paris Green, $Cu_4(AsO_3)_2(CH_3CO_2)_2$
(c) 325 mg of aspirin, $C_6H_4(CO_2H)(CO_2CH_3)$

(a) $\frac{25\ lb}{1\ lb}\ \frac{454\ g}{283.26\ g}\ \frac{1\ mol}{}$ = 40 mol
X 13 = 520 mol C
X 16 = 640 mol H
X 2 = 80 mol N
X 4 = 160 mol O
X 1 = 40 mol F

(b) $\frac{0.125\ kg}{1\ kg}\ \frac{1\ E3\ g}{618.04\ g}\ \frac{1\ mol}{}$ = 0.202 mol
X 4 = 0.808 mol Cu
X 2 = 0.404 mol As
X 10 = 2.02 mol O
X 4 = 0.808 mol C
X 6 = 1.212 mol H

(c) $\frac{325\ mg}{1\ E3\ mg}\ \frac{1\ g}{180.13\ g}\ \frac{1\ mol}{}$ = 1.80 E-3 mol
X 9 = 1.62 E-2 mol C
X 8 = 1.44 E-2 mol H
X 4 = 7.20 E-3 mol O

5. Determine the mass of each of the following:
(a) 6.854 E3 mol glucose, $C_6H_{12}O_6$
(b) 2.86 mol $Co(NH_3)_6Cl_3$

(a) $\frac{6.854\ E3\ mol}{}\ \frac{180.18\ g}{1\ mol}$ = 1.235 E6 g

(b) $\frac{2.86\ mol}{}\ \frac{267.52\ g}{1\ mol}$ = 765 g

6. Determine which of the following contains the greatest mass of hydrogen: 1 mol of CH_4, 0.6 mol of C_6H_6, or 0.4 mol of C_3H_8.

$\frac{1\ mol\ CH_4}{1\ mol\ CH_4}\ \frac{4\ mol\ H}{1\ mol\ H}\ \frac{1.01\ g}{}$ = 4.04 g ←

$\frac{0.6\ mol\ C_6H_6}{1\ mol\ C_6H_6}\ \frac{6\ mol\ H}{1\ mol\ H}\ \frac{1.01\ g}{}$ = 3.64 g

$\frac{0.4\ mol\ C_3H_8}{1\ mol\ C_3H_8}\ \frac{8\ mol\ H}{1\ mol\ H}\ \frac{1.01\ g}{}$ = 3.23 g

7. One 55-gram serving of a particular cereal supplies 270 mg of sodium, 11% of the recommended daily allowance. How many moles and atoms of sodium are in the recommended daily allowance?

100 / 11 = $\frac{9.09\ \ 270\ mg}{1\ E3\ mg}\ \frac{1\ g}{22.99\ g}\ \frac{1\ mol\ Na}{}$ = $\frac{0.107\ mol}{1\ mol}\ \frac{6.02\ E23\ atoms\ Na}{}$ = **6.43 E22**

3.2: Determining empirical & molecular formulas

8. Calculate the percent composition of $Ca_3(PO_4)_2$ to four significant figures.

MW = 310.10 g/mol

Ca = $\frac{120.24}{310.10}$ (100) = 38.8%

P = $\frac{61.94}{310.10}$ (100) = 20.0%

O = $\frac{127.92}{310.10}$ (100) = 41.3%

9. A sample contains 5.31 g of Cl and 8.40 g of O. What's its empirical formula?

Cl $\frac{5.31\text{ g}}{35.45\text{ g}} \frac{1\text{ mol}}{} = 0.150\text{ mol} / 0.150 = 1 \times 2 = 2$

O $\frac{8.40\text{ g}}{15.99\text{ g}} \frac{1\text{ mol}}{} = 0.525\text{ mol} / 0.150 = 3.5 \times 2 = 7$

So, Cl_2O_7

10. Yeast are used to ferment grain and produce alcohol. Fermentation also produces a gas whose percent composition is 27.29% C and 72.71% O. What's the empirical formula of the gas?

C $\frac{27.29\text{ g}}{12.01\text{ g}} \frac{1\text{ mol}}{} = 2.272\text{ mol} / 2.272 = 1$

O $\frac{72.71\text{ g}}{15.99\text{ g}} \frac{1\text{ mol}}{} = 4.547\text{ mol} / 2.272 = 2$

So, CO_2

11. Distilled white vinegar is a solution of acetic acid (CH_3COOH) in water. A 0.500-L solution of vinegar contains 25.2 g of acetic acid. What is the concentration (M) of acetic acid in the vinegar?

MW = 60.04 g/mol

$\frac{25.2\text{ g}}{60.04\text{ g}} \frac{1\text{ mol}}{0.500\text{ L}} = \frac{0.839\text{ mol}}{1\text{ L}} = M$

12. Determine the empirical and molecular formula for chrysotile asbestos. Chrysotile has the following percent composition: 28.03% Mg, 21.60% Si, 1.16% H, and 49.21% O. The molar mass for chrysotile is 520.8 g/mol.

$\frac{28.03\text{ g}}{24.31\text{ g}} \frac{1\text{ mol}}{} = 1.153\text{ mol Mg}$ $\frac{21.60\text{ g}}{28.08\text{ g}} \frac{1\text{ mol}}{} = 0.769\text{ mol Si}$ $\frac{1.16\text{ g}}{1.01\text{ g}} \frac{1\text{ mol}}{} = 1.15\text{ mol H}$

$\frac{49.21\text{ g}}{15.99\text{ g}} \frac{1\text{ mol}}{} = 3.08\text{ mol O}$

Divide all by 0.769 mol

Mg = 1.50 X 2 = 3

Si = 1 X 2 = 2

H = 1.50 X 2 = 3

O = 4 X 2 = 8

$Mg_3Si_2H_3O_8$ = 260.04 g/mol

MW = $\frac{520.8\text{ g/mol}}{260.04\text{ g/mol}}$ = 2 $Mg_6Si_4H_6O_{16}$
EW

3.3: Molarity

13. Determine the molarity for each of the following solutions:

(a) 10.5 kg of $Na_2(SO_4)\cdot 10H_2O$ in 18.60 L of solution

(b) 7.0×10^{-3} mol of I_2 in 100.0 mL of solution

(c) 1.8×10^{4} mg of HCl in 0.075 L of solution

(a) $\frac{10.5\ \text{kg}}{1}\times\frac{1\text{ E3 g}}{1\ \text{kg}}\times\frac{1\ \text{mol}}{322.20\ \text{g}}\times\frac{}{18.60\ \text{L}} = 1.75\ \text{M}$

(b) $\frac{7.0\text{ E-3 mol}}{0.10000\ \text{L}} = 0.070\ \text{M}$

(c) $\frac{1.8\text{ E4 mg}}{1}\times\frac{1\ \text{g}}{1\text{ E3 mg}}\times\frac{1\ \text{mol}}{36.46\ \text{g}}\times\frac{}{0.075\ \text{L}} = 6.6\ \text{M}$

14. Calculate the number of moles and the mass of the solute in each of these following solutions:

(a) 5.50 L of 13.3 M H_2CO, the formaldehyde used to "fix" tissue samples

(b) 325 mL of 1.8×10^{-6} M $Fe(SO_4)$, the minimum concentration of iron sulfate detectable by taste in drinking water

(a) $\frac{5.50\ \text{L}}{1}\times\frac{13.3\ \text{mol}}{1\ \text{L}} = \frac{73.2\ \text{mol}}{1}\times\frac{30.02\ \text{g}}{1\ \text{mol}} = 2.20\text{ E3 g}$

(b) $\frac{325\ \text{mL}}{1}\times\frac{1\ \text{L}}{1\text{ E3 mL}}\times\frac{1.8\text{ E-6 mol}}{1\ \text{L}} = \frac{5.85\text{ E-7 mol}}{1}\times\frac{151.87\ \text{g}}{1\ \text{mol}} = 8.88\text{ E-5 g}$

15. Calculate the molarity of each of the following solutions:

(a) 1.49 kg of isopropyl alcohol, C_3H_7OH, in 2.50 L of solution, the concentration of isopropyl alcohol in rubbing alcohol

(b) 0.029 g of I_2 in 0.100 L of solution, the solubility of I_2 in water at 20 °C

(a) $\frac{1.49\ \text{kg}}{1}\times\frac{1\text{ E3 g}}{1\ \text{kg}}\times\frac{1\ \text{mol}}{60.10\ \text{g}}\times\frac{}{2.50\ \text{L}} = 9.92\ \text{M}$

(b) $\frac{0.029\ \text{g}}{1}\times\frac{1\ \text{mol}}{253.80\ \text{g}}\times\frac{}{0.100\ \text{L}} = 1.1\text{ E-3 M}$

16. There is about 1.0 g of calcium, as Ca^{2+}, in 1.0 L of milk. What is the molarity of Ca^{2+} in milk?

$\frac{1.0\ \text{g}}{1}\times\frac{1\ \text{mol}}{40.08\ \text{g}}\times\frac{}{1.0\ \text{L}} = 2.5\text{ E-2 M}$

17. What is the molarity of the diluted solution when each of the following solutions is diluted to the given final volume?

(a) 2.35 L of a 0.350-M solution of $H_3(PO_4)$ is diluted to a final volume of 4.00 L

(b) 22.50 mL of a 0.025-M solution of $C_{12}H_{22}O_{11}$ is diluted to 100.0 mL

(a) $\frac{(2.35\ \text{L})(0.350\ \text{M})}{4.00\ \text{L}} = \frac{\cancel{(4.00\ \text{L})}(\text{X M})}{} = 0.206\ \text{M}$

(b) $\frac{(22.50\ \text{mL})(0.025\ \text{M})}{100.0\ \text{mL}} = \frac{\cancel{(100.0\ \text{mL})}(\text{X M})}{} = 5.625\text{ E-3 M}$

18. A 2.00-L bottle of a solution of concentrated HCl was purchased for the general chemistry laboratory. The solution contained 868.8 g of HCl. What is the molarity of the solution?

$$\frac{868.8\ \text{g}}{}\ \frac{1\ \text{mol}}{36.46\ \text{g}}\ \frac{}{2.00\ \text{L}} = 11.91\ \text{M}$$

19. The US Environmental Protection Agency (EPA) places limits on the quantities of toxic substances that may be discharged into the sewer system. Limits have been established for a variety of substances, including hexavalent chromium, which is limited to 0.50 mg/L. If an industry is discharging hexavalent chromium as potassium dichromate ($K_2Cr_2O_7$), what is the maximum permissible molarity of that substance?

$$\frac{0.50\ \text{mg}}{1\ \text{L}}\ \frac{1\ \text{g}}{1\ \text{E3 mg}}\ \frac{1\ \text{mol}}{294.11\ \text{g}} = 1.7\ \text{E-6 M}$$

3.4: Other units for solution concentration *[optional]*

20. Consider this question: What mass of a concentrated solution of nitric acid (68.0% $H(NO_3)$ by mass) is needed to prepare 400.0 g of a 10.0% solution of $H(NO_3)$ by mass?
(a) Outline the steps necessary to answer the question.
(b) Answer the question.
(a) Use the dilution formula.
(b) ~~(68.0%)~~(X g) = $\frac{(10.0\%)(400.0\ \text{g})}{68.0\%}$ = 58.8 g

21. What mass of a 4.00% Na(OH) solution by mass contains 15.0 g of Na(OH)?

$$4.00\% = \frac{15.0\ \text{g Na(OH)}}{\text{g sol'n}}(100) \rightarrow \frac{15.0\ \text{g Na(OH)}\ (100)}{4.00\%} = 375\ \text{g}$$

22. What mass of solid Na(OH) (97.0% Na(OH) by mass) is required to prepare 1.00 L of a 10.0% solution of Na(OH) by mass? The density of the 10.0% solution is 1.109 g/mL.

$$10\% = \frac{\text{g Na(OH)}}{(1\ \text{E3 mL})(1.109\ \text{g/mL})}(100) \rightarrow \frac{(10\\%)(1\ \text{E3 mL})(1.109\ \text{g/mL})}{100} = \text{g Na(OH)} = 110.9\ \text{g}$$

$$\frac{110.9\ \text{g}}{100\%} = \frac{\text{X g}}{97.0\%} \rightarrow 107.6\ \text{g of 97\% (solid) Na(OH)}$$

23. The level of mercury in a stream was suspected to be above the minimum considered safe (1 part per billion by weight). An analysis indicated that the concentration was 0.68 parts per billion. Assume a density of 1.0 g/mL and calculate the molarity of mercury in the stream.

$$0.68\ \text{ppb} = \frac{\text{g Hg}}{(1\ \text{E3 mL})(1.0\ \text{g/mL})}(1\ \text{E9 ppb}) \rightarrow \frac{(0.68\ \text{ppb})(1\ \text{E3 mL})(1.0\ \text{g/mL})}{1\ \text{E9 ppb}} = 6.8\ \text{E-7 g Hg}$$

$$\frac{6.8\ \text{E-7 g}}{1\ \text{L}}\ \frac{1\ \text{mol}}{200.59\ \text{g}} = 3.0\ \text{E-9 M}$$

24. In Canada and the United Kingdom, devices that measure blood glucose levels provide a reading in millimoles per liter. If a measurement of 5.3 mM is observed, what is the concentration of glucose ($C_6H_{12}O_6$) in mg/dL?

$$\frac{5.3\ \text{mmol}}{1\ \text{L}} \times \frac{1\ \text{L}}{10\ \text{dL}} \times \frac{1\ \text{mol}}{1\ \text{E3 mmol}} \times \frac{180.12\ \text{g}}{1\ \text{mol}} \times \frac{1\ \text{E3 mg}}{1\ \text{g}} = 95\ \text{mg/dL}$$

25. Copper (I) iodide (CuI) is often added to table salt as a dietary source of iodine. How many moles of CuI are contained in 1.00 lb (454 g) of table salt containing 0.0100% CuI by mass?

$$\frac{1.00\ \text{lb}}{1\ \text{lb}} \times \frac{454\ \text{g}}{} \times \frac{0.0001000}{} \times \frac{1\ \text{mol}}{190.45\ \text{g}} = 2.38\ \text{E-4 mol CuI}$$

26. D5W is a solution used as an intravenous fluid. It is a 5.0% by mass solution of dextrose ($C_6H_{12}O_6$) in water. If the density of D5W is 1.029 g/mL, calculate the molarity of dextrose in the solution.

$$5.0\% = \frac{\text{g dextrose}}{(1\ \text{E3 mL})(1.029\ \text{g/mL})}(100) \rightarrow \text{g} = \frac{(5.0\%)(1\ \text{E3 mL})(1.029\ \text{g/mL})}{100} = 51\ \text{g}$$

$$\frac{51\ \text{g}}{1} \times \frac{1\ \text{mol}}{180.12\ \text{g}} \times \frac{}{1\text{L}} = 0.28\ \text{M}$$