CHEMISTRY 135 PRACTICE EXERCISE
STOICHIOMETRY

Do not submit this work for a grade but discuss your answers with your lecturer to make sure that you are performing up to standard. You may be tested on your understanding of it in class. Make sure you give your answers to the same degree of accuracy as the least accurate piece of data given in the question. Remember that in test no marks are awarded for a correct answer if it is unsupported by working and marks are awarded for the clarity and correctness of working.

1) a) How many moles of hydrogen atoms are there in 1 mole of water?
   b) How many moles of hydrogen gas could be produced by the complete decomposition of 1 mole of water?
   c) What volume would the hydrogen produced in (b) above occupy at
      i) s.t.p.?
      ii) 300°C and 5 atm pressure?
   d) i) How many chlorine atoms are there in 0.1 mol of tetrachloromethane, CCl_4?
      ii) How many chlorine molecules could be formed from this number of atoms?
2) 0.240 mole of tungsten (W) are mixed with 3.84g of sulphur. The mixture is heated so that a compound, tungsten sulphide (WS3), is formed. What mass of this compound is formed?
3) 1.15889 g of a certain element, chemical symbol X, displaced 2.5826g of gold from a gold bromide solution. The equation for the reaction is:

   $3X(s) + 2Au_3^+(aq) \rightarrow 3X_2^+(aq) + 2Au(s)$

   If the relative atomic mass of gold is 197.0, find the relative atomic mass of X. How many significant figures are appropriate to your answer?
4) a) If 12 molecules of hydrogen and 5 molecules of oxygen are mixed together, how many molecules of water can be formed?
   b) If 20 molecules of hydrogen and 5 molecules of oxygen are mixed together, how many molecules of water can be formed?
   c) How many molecules of water can be formed from 8 molecules of hydrogen and 5 molecules of oxygen?
   d) In each of the above cases how many molecules are left unreacted, and of what kind are they?
5) How many moles of H_2 molecules are needed to convert 5 moles of O_2 molecules to water?
6) How many moles of H_2 molecules are needed to convert 5 moles of O_2 molecules to hydrogen peroxide?
7) Calculate the total number of moles of product produced when 2 mol of nitroglycerin decompose according to the equation:

   $4C_3H_5O_9N_3(l) \rightarrow 6N_2(g) + 12CO_2(g) + 10H_2O(g) + O_2(g)$

   The density of nitroglycerin is $1.594\ g\ cm^{-3}$. When it decomposes it does so extremely rapidly and a great deal of heat is generated, raising the temperature of the products to about 2000°C.
   a) Calculate the mass of the nitroglycerin used.
   b) Calculate the original volume of the nitroglycerin.
   c) Calculate the pressure the gases would generate at this temperature if confined to the original volume of the nitroglycerin. (Assume the gases would behave ideally.)
   d) Considering your answer to (c) above explain how and why the decomposition is explosive.
   e) Do you think the gases would behave ideally under these conditions? Would the real pressure be greater or less than that calculated in part (c) above?

8) Calculate the mass and volume (at 25°C and 750 mmHg pressure) of the carbon dioxide produced by the thermal decomposition of 10 g of calcium carbonate.

9) Calculate the mass of alumina produced and the volume of oxygen consumed (at 100 000 Pa and 30°C) when 100g of aluminium is burned in air.

10) The compound diborane (B_2H_6) was at one time considered as a rocket fuel. How many tonnes (1 tonne = 1000 kg) of liquid oxygen would a rocket have to carry to burn 10 metric tonnes of diborane completely to B2O3 and water?

11) The solid fuel in the booster of the American space shuttle actually uses a mixture of ammonium chlorate(VII) and aluminium powder. These react according to the equation:

$6NH_4ClO_4(s) + 10Al(s) \rightarrow 5Al_2O_3(s) + 3N_2(g) + 6HCl(g) + 9H_2O(g)$

What mass of aluminium should be mixed with 5 tonnes of ammonium chlorate(VII) for best results?

12) What is the maximum mass of glucose ($C_6H_{12}O_6$) that can be burned completely to carbon dioxide and water if only 10 g of oxygen is available?

13) A solution containing 5.0 g of silver nitrate was mixed with another containing 5.0 g of potassium chloride.

a) Which is the limiting reagent?

b) What mass of precipitate will be formed?

c) What mass of which reagent will remain unreacted?

14) When xenon difluoride dissolves in water, it slowly reacts with the water to produce xenon gas, hydrogen fluoride, and oxygen:

$2XeF_2(aq) + 2H_2O(l) \rightarrow 2Xe(g) + 4HF(g) + O_2(g)$

Which is the limiting reagent when 1.0 g of the difluoride is dissolved in 50 g of water? What mass of hydrogen fluoride is produced?

15) The theoretical yield of ammonia in an industrial process was 550 tons, but only 480 tons was obtained. What was the percentage yield of the reaction?

16) In the following questions calculate the molecular formula, given the empirical formula and the relative molecular mass:

a) CH_2, 140

b) CH_2O, 180

c) C_5H_7N, 162

d) NH_2, 32

17) A certain acid was isolated from rhubarb. Analysis of a sample of the acid showed that it contained 27% C, 2.2% H, and 71% O. What is its empirical formula?

18) In an experiment 4.14 g of the element phosphorus combined with chlorine to give 27.8 g of a white solid compound. What is the empirical formula of the compound?

19) An analysis of the substance cocaine shows that it consists of 67.31% C, 6.98% H, 21.10% O, and 4.62% N. Given that its relative molecular mass is 303, what is its empirical and its molecular formula.

20) An alkaloid derived from tobacco was found to have a relative molecular mass of 162. When a 0.395 g sample was burned 1.072 g of carbon dioxide, 0.307 g of water, and 0.068 g of nitrogen were produced. What are the empirical and molecular formulae of the alkaloid, given that it contained carbon, hydrogen and nitrogen only?

21) 1.230 g of sodium chloride were dissolved in enough water to make 100 cm^3 of solution. Calculate its molar concentration.

22) A chemist studying the properties of photographic emulsions decided to make a 0.100 M solution of silver nitrate by adding the salt to a 50.0 cm^3 flask and then making up to the mark with water. What mass of the salt did he weigh out?

23) A solution of anhydrous sodium carbonate was made up by adding 5.150 g to a 250.0 cm^3 volumetric flask and adding water up to the mark.

a) What volume of the solution contains 4.20 mmol of sodium carbonate?

b) What volume of the solution contains 4.20 mmol of sodium ions?

c) What volume of the solution contains 4.20 mmol of carbonate ions?

d) If 5.150 g of sodium carbonate decahydrate had been used instead of the anhydrous salt, what volume would now be required to contain 4.20 mmol of sodium carbonate?

24) A solution was prepared by weighing 6.120 g of sodium ethanoate ($NaC_2H_3O_2$) into a 500.0 cm^3 volumetric flask and making up to the mark. 50.00 cm^3 of this solution were transferred to a second volumetric flask and then diluted to 250.0 cm^3 with water.

a) What is the concentration of the final solution?

b) If 0.1 M sodium ethanoate solution had been used by accident instead of water for the final dilution to 250.0 cm^3, what would have been the final concentration in this case?

25) A solution was prepared by dissolving 4.05 g of sodium hydroxide in enough water to make 150.0 cm^3 of solution. It was found that 25.00 cm^3 of this solution required 14.84 cm^3 of hydrochloric acid to reach the equivalence point. If the molar concentration of the acid is 1.097 M, what is the percentage purity of the sodium hydroxide used?. What assumptions are your figure based on?

26) The concentration of nitrite ions (NO_2^-) in a solution can be determined by back-titration of unused Ce(IV) after using Ce(IV) in excess as an oxidising agent:

$2Ce^{4+}(aq) + NO^{2-}(aq) + H_2O(l) \rightarrow 2Ce^{3+}(aq) + NO_3^- + 2H^+(aq)$

In one experiment, a 0.254 g sample containing sodium nitrite and inert materials was treated with 25.00 cm^3 of 0.122 M Ce(IV) solution. The excess cerium(IV) was then back-titrated with 13.20 cm^3 of 0.0154 M $Fe^{2+}(aq)$. Calculate the percentage by mass of $NaNO_2$ in the sample. The reaction between Ce(IV) and Fe(II) is:

$Fe^{2+}(aq) + Ce^{4+}(aq) \rightarrow Fe^{3+}(aq) + Ce^{3+}(aq)$

27) 2.513 g of a mixture of anhydrous potassium and sodium carbonates was dissolved in water. The solution was made up to 250 cm^3 in a volumetric flask and mixed thoroughly. A 25.0 cm^3 aliquot of this solution was titrated with 0.212 M hydrochloric acid. The mean of three concordant titres was 19.98 cm^3. Calculate the percentage mass of potassium carbonate in the mixture.

28) 9.8 cm^3 of a gaseous hydrocarbon was mixed with excess oxygen to a total volume of 107.8 cm^3. The mixture was ignited and then adjusted to the original temperature and pressure. After drying, the total volume of gas was found to be 73.5 cm^3. After shaking with concentrated sodium hydroxide solution the volume decreased to 24.5 cm^3. Determine the molecular formula of the hydrocarbon.

29) 10.0g of a mixture of mercury(I) oxide and lead(IV) oxide were heated strongly. Under these conditions the mercury(I) oxide decomposes to mercury and oxygen, and the lead(IV) oxide decomposes to lead(II) oxide and oxygen. The gas given off was collected over water at a pressure of 765 mmHg and 27°C. Its volume was measured as 439 cm^3. Calculate the mass of mercury(I) oxide in the mixture given that the vapour pressure of water at this temperature and pressure is 27 mmHg.

30) Iron has a molar mass of 55.8 g mol^{-1} and a density of 7.86 g cm^{-3}. In the following question you can assume that iron atoms are hard spheres.

a) What is the density of iron in g dm^{-3}?

b) What is the molar volume of iron in

i) $dm^3 mol^{-1}$?

ii) $cm^3 mol^{-1}$

c) Calculate the average volume occupied by an iron atom in cm^3. (Pretend that the atoms occupy all of the volume taken up by a lump of iron, ie. that there are no gaps between the atoms.)

d) If the true radius of an iron atom is 1.24×10^{-10} m, what is its volume in cm^3?

e) What percentage of a piece of iron consists of gaps between atoms?

f) The electrons in atoms occupy no space in themselves, they just keep the nuclei apart. If the volume of the nucleus of an iron atom is about $1.6\times10^{-36} cm^3$, what percentage of a piece of iron is empty space?.

g) The figure given above for the density of iron tells you that 7.86 g of iron occupies a

volume of 1 cm^3. What volume (in cm^3) would it occupy at s.t.p. if it were a gas? Compare these two figures and comment on the difference between them.

31) 1.00 g of magnesium is added to 100 cm^3 of 0.123 M hydrochloric acid solution. Calculate the volume of hydrogen which could be collected over water at 25°C. (At. pr. = 755 mmHg, svp of water @ 25°C = 24 mmgHg.)

32) 25 cm^3 of a gaseous hydrocarbon are are mixed with 250 cm^3 of oxygen (excess) and the mixture ignited. After cooling the residual gases occupied 175 cm^3, and this was reduced to 50 cm^3 after shaking with concentrated sodium hydroxide solution. Find the molecular formula of the hydrocarbon given that all volumes are measured under the same conditions of temperature and pressure.

33) A compound of carbon, hydrogen and oxygen only, occupies 104 cm^3 at 150°C, at which temperature it is a gas. 350 cm^3 of oxygen (excess) are added and the mixture ignited. After cooling to the original temperature the volume is found to be 558 cm^3. This volume shrinks to 246 cm^3 after drying with anhydrous calcium chloride, and then to 38 cm^3 after shaking with concentrated potassium hydroxide solution. Find the formula of the compound given that all gas volumes are measured under the same conditions of temperature and pressure.

ANSWERS TO PROBLEMS

1) a) 2 mol

b) 1 mol

c) i) 22.4 dm^3

ii) 9.40 dm^3

d) i) 2.4×10^{23}

ii) 1.2×10^{23}

2) 11.2 g

3) 58.933, 5 sig. figs.

4) a) 10 molecules of water.

b) 10 molecules of water.

c) 8 molecules of water.

d) (a) 2 molecules of hydrogen, (b) 10 molecules of hydrogen, (c) 1 molecule of oxygen.

5) 10 mol

6) 5 mol

7) 14.5 mol

7 a) 454 g

7 b) 285 cm^3

7 c) 9.6×10^8Pa or 9 500 atm

7 d) The gas behaves far from ideally since the molecules are very close together. The volume occupied by the molecules is a large proportion of the volume of the gas and forces of attraction are also large. The pressure would be higher than the ideal pressure since $PV \gg nRT$ at high pressures.

8)4.4 g, 2.48 dm^3

9) 189 g, 70.0 dm^3

10) 34.8tonnes

11) 1.91 tonnes

12) 9.37 g

13 a) $AgNO_3$

13 b) 4.22 g

13 c) 2.81 g KCl

14) XeF_2, 0.236 g

15) 87.3%

16 a) $C_{10}H_{20}$

16 b) $C_6H_{12}O_6$

16 c) $C_{10}H_{14}N_2$

16 d) N_2H_4

17) CHO_2

18) PCl_5

19) $C_{17}H_{21}O_4N$

20) C_5H_7N, $C_{10}H_{14}N_2$

21) 0.210 M

22) 0.85 g

23 a) 21.6 cm^3

23 b) 10.8 cm^3

23 c) 21.6 cm^3

23 d) 58.3 cm^3

24 a) 0.0298 M

24 b) 0.110 M

25) 96.52%; the assumptions are that the sample contains no basic substances other than sodium hydroxide, and no insoluble matter.

26) 38.7%

27) 46.0%

28) C_5H_{10}

29) 40.5%

30) a)7860 g dm^3

b) 7.13 cm^3mol^{-1}

c) $1.184\times10^{-23}cm^3$

d)$7.99\times10^{-24}cm^3$

e) 32.6%

f)Virtually 100% (100% - 1.3×10^{-11}%)

g) 3140 cm^3

31) 156 cm^3

32) C_5H_{12}

33) C_2H_6