KEY

Chemistry 20 FINAL REVIEW (2015)

Unit D: Stoichiometry

General Outcome 1
Students will explain how balanced chemical equations indicate the quantitative relationships between reactants and products involved in chemical changes.

Students will:
20–D1.1k predict the product(s) of a chemical reaction based upon the reaction type

20–D1.2k recall the balancing of chemical equations in terms of atoms, molecules and moles

20–D1.4k write balanced ionic and net ionic equations, including identification of spectator ions, for reactions taking place in aqueous solutions

Students will:
20–D1.2s conduct investigations into relationships among observable variables and use a broad range of tools and techniques to gather and record data and information
• translate word equations for chemical reactions into chemical equations, including states of matter for the products and reactants
• balance chemical equations for chemical reactions, using lowest whole-number coefficients

Create a balance molecular equation, a total ionic equation and a net ionic equation for each of the following reactions described below:

1. A reaction of sodium hydroxide with ammonium carbonate

$2NaOH(aq) + 1(NH_4)_2CO_3(aq) \rightarrow 1Na_2CO_3(aq) + 2NH_4OH(aq)$

$2Na^+(aq) + 2OH^-(aq) + 2NH_4^+(aq) + CO_3^{2-}(aq) \rightarrow 2Na^+(aq) + CO_3^{2-}(aq) + 2NH_4^+(aq) + 2OH^-(aq)$

No Net as all ions cancel!

2. A reaction of lithium sulfate with gold(III)fluoride

$3Li_2SO_4(aq) + 2AuF_3(aq) \rightarrow 6LiF(s) + 1Au_2(SO_4)_3(aq)$

$6Li^+(aq) + 3SO_4^{2-}(aq) + 2Au^{3+}(aq) + 6F^-(aq) \rightarrow 6LiF(s) + 2Au^{3+}(aq) + 3SO_4^{2-}(aq)$

$6Li^+(aq) + 6F^-(aq) \rightarrow 6LiF(s)$

3. A reaction of rubidium iodate with lead(II)nitrate

$2RbIO_3(aq) + 1Pb(NO_3)_2(aq) \rightarrow 2RbNO_3(aq) + 1Pb(IO_3)_2(s)$

$2Rb^+(aq) + 2IO_3^-(aq) + 1Pb^{2+}(aq) + 2NO_3^-(aq) \rightarrow 2Rb^+(aq) + 2NO_3^-(aq) + 1Pb(IO_3)_2(s)$

$2IO_3^-(aq) + 1Pb^{2+}(aq) \rightarrow 1Pb(IO_3)_2(s)$

20–D1.5k calculate the quantities of reactants and/or products involved in chemical reactions, using gravimetric, solution or gas stoichiometry

1. a. Determine the balanced chemical reaction occurring when pentane (C_5H_{12}) burns

$1C_5H_{12} + 8O_2 \rightarrow 5CO_2 + 6H_2O$

b. What mass of $CO_2(g)$ is produced when 10.0g of pentane is burned?

$\#g\ CO_2 = 10g\ C_5H_{12} \times \frac{1\ mol}{72.17\ g} \times \frac{5\ CO_2}{1\ C_5H_{12}} \times \frac{44.01\ g}{1\ mol} = \boxed{30.5\ g\ CO_2}$

c. What mass of $H_2O(l)$ is made when the burning of pentane gives 106L of CO_2 at 98kPa and 36C?

$n = \frac{PV}{RT}$

$\#g\ H_2O = \frac{(98\ kPa)(106\ L)}{(8.314)(309\ K)} \times \frac{6\ H_2O}{5\ CO_2} \times \frac{18.02\ g}{1\ mol} = \boxed{87\ g\ H_2O}$

2. Tetraethyl lead $Pb(C_2H_5)_4$ is an antiknock ingredient which was added to some gasolines. Tetraethyle lead burns according to the equation

$$2Pb(C_2H_5)_4 + 27O_2(g) \rightarrow 2PbO(s) + 16CO_2 + 20H_2O$$

a. What volume of oxygen is consumed when 100.0g of PbO(s) are formed?

$$\#L\ O_2 = 100g\ PbO \times \frac{1\ mol}{223.2\ g} \times \frac{27\ O_2}{2\ PbO} \times \frac{22.4\ L}{1\ mol} = \boxed{135.5\ L\ O_2}$$

b. How many molecules of carbon dioxide are formed when 1.00x10-6g of tetraethyl lead is burned?

$$\#\ molec\ CO_2 = 1.0 \times 10^{-6}\ g \times \frac{1\ mol}{323.44g} \times \frac{16CO_2}{2\ Pb(C_2H_5)_4} \times \frac{6.02 \times 10^{23}\ molec}{1\ mol} = \boxed{1.49 \times 10^{16}\ molec\ CO_2}$$

c. How many molecules of water are formed when 135 molecules of oxygen react?

$$\#\ molec\ H_2O = 135\ molec\ O_2 \times \frac{1\ mol}{6.02 \times 10^{23}\ molec} \times \frac{20\ H_2O}{27\ O_2} \times \frac{6.02 \times 10^{23}\ molec}{1\ mol} = \boxed{100.\ molec\ O_2}$$

d. What volume of oxygen in millilitres is required to react with 1.00x1015molecules of tetraethyl lead?

$$\#\ mL\ O_2 = 1.0 \times 10^{15}\ molec \times \frac{1\ mol}{6.02 \times 10^{23}\ molec} \times \frac{27\ O_2}{2\ Pb(C_2H_5)_4} \times \frac{22.4\ L}{1\ mol} \times \frac{1000\ mL}{1\ L} = \boxed{5.02 \times 10^{-4}\ mL\ O_2}$$

3. One of the most efficient drying agents known is P_4O_{10} in fact, P_4O_{10} will even remove water from pure H_2SO_4 to produce SO_3

$$1\ P_4O_{10}(s) + 6\ H_2SO_4(l) \rightarrow 4H_3PO_4(aq) + 6SO_3(g)$$

Pure $H_2SO_4(l)$ has a density of 1.84g/mL. If 25.0mL of $H_2SO_4(l)$ react, what mass of $P_4O_{10}(s)$ also reacts and what volume of $SO_3(g)$ at STP is produced?

$$\#g\ P_4O_{10} = \frac{1.84\ g}{mL} \times 25mL\ H_2SO_4 \times \frac{1\ mol}{98.08\ g} \times \frac{1\ P_4O_{10}}{6H_2SO_4} \times \frac{283.88\ g}{1\ mol} = \boxed{22.2\ g\ P_4O_{10}}$$

$$\#L\ SO_3 = 22.2g\ P_4O_{10} \times \frac{1\ mol}{283.88g} \times \frac{6\ SO_3}{1\ P_4O_{10}} \times \frac{22.4L}{1\ mol} = \boxed{10.5\ L\ SO_3}$$

4. Ozone, O_3 in the upper atmosphere protects the earth from the sun's harmful UV radiation. One step in the destruction of the ozone layer by chlorine containing compounds is $Cl(g) + O_3(g) \rightarrow ClO(g) + O_2(g)$. The volume of ozone in the upper atmosphere is estimated to be 1.5x1015L at STP. Each Cl atom is continually "recycled" so as to be capable of destroying an average of about 1.0x105 molcules of ozone. What mass of Cl atoms woud be required to use us the available ozone if the ozone were not "regenerated".

$$\#g\ Cl = 1.5 \times 10^{15}\ L\ O_3 \times \frac{1\ mol}{22.4\ L} \times \frac{1\ Cl}{1.0 \times 10^5\ O_3} \times \frac{35.5\ g\ Cl}{1\ mol} = \boxed{2.4 \times 10^{10}\ g\ Cl}$$

5. a. A 1.00mL sample of pure phosphorice acid is titrated with 43.8mL of 0.853M NaOH, what is the molarity of the pure phosphoric acid?

$$3\ NaOH + 1H_3PO_4 \rightarrow 1\ Na_3PO_4 + 3H_2O$$

$$\frac{mol}{L}\ H_3PO_4 = \frac{0.853\ mol}{L} \times 0.0438\ L \times \frac{1\ H_3PO_4}{3\ NaOH} \times \frac{1}{0.001\ L} = \boxed{12.5\ M\ H_3PO_4}$$

b. Calculate the density of pure phosphoric acid.

$$\frac{\#g}{mL} = \frac{12.5\ mol}{L} \times \frac{1\ L}{1000\ mL} \times \frac{98\ g}{1\ mol} = \boxed{\frac{1.23\ g}{mL}\ H_3PO_4}$$

Students will:
20–D1.1sts explain that the products of technology are devices, systems and processes that meet given needs; however, these products cannot solve all problems
• analyze the chemical reactions involved in various industrial and commercial processes and products that use stoichiometric and chemical principles:
– production of urea
– fertilizers
– fuel combustion
– water treatment
– air bag deployment
- neutralization of excess stomach acid

General Outcome 2
Students will use stoichiometry in quantitative analysis.

20–D1.3k contrast quantitative and qualitative analysis

Students will:
20–D2.1k explain chemical principles (i.e., conservation of mass in a chemical change), using quantitative analysis

Complete the following chart below

	Qualitative Analysis	Quantitative Analysis	Conservation of Mass
Definition	observations	amounts	no matter is created nor destroyed
Example	color change	conc of unknown	Burning organic to produce CO_2 and H_2O
Why is this important to chemistry ?	observe result	results	stoich
Lab Design (how would you test this concept)	flame test	titration	

20–D2.2k identify limiting and excess reagents in chemical reactions

1. a. What mass of CS_2 is produced when 17.5g of C are reacted with 39.5g of SO_2 to produce CS_2 and CO(g)?

$5C + 2SO_2 \rightarrow 1CS_2 + 4CO$

$\#g\ CS_2 = \frac{17.5g}{C} \times \frac{1mol}{12.01} \times \frac{1CS_2}{5C} \times \frac{76.14g}{1mol} = \boxed{22.189g}$

$\#g\ CS_2 = \frac{39.5g}{SO_2} \times \frac{1mol}{64.07g} \times \frac{1CS_2}{2SO_2} \times \frac{76.14g}{1mol} = 23.47g$

b. What mass of the excess reactant will be left over?

LR = C

$\#g\ SO_2\ used = \frac{17.5g}{C} \times \frac{1mol}{12.01g} \times \frac{2SO_2}{5C} \times \frac{64.07g}{1mol} = 37.343g\ SO_2\ used$

$Excess = 39.5g - 37.343g = \boxed{2.157g\ excess\ SO_2}$

2. a. What mass of NO is produced when 87.0g of Cu are reacted with 225g of HNO_3 to produce $Cu(NO_3)_2$ and nitrogen monoxide and water?

$$3Cu + 8HNO_3 \rightarrow 3Cu(NO_3)_2 + 2NO + 4H_2O$$

$$\#g\ NO = 87.0g\ Cu \times \frac{1 mol}{63.55g} \times \frac{2\ NO}{3\ Cu} \times \frac{30.01g}{1 mol} = 27.39\ g\ NO$$

$$\#g\ NO = 225g\ HNO_3 \times \frac{1 mol}{63.01g} \times \frac{2\ NO}{8\ HNO_3} \times \frac{30.01g}{1 mol} = \boxed{26.79\ g\ NO}$$

b. What mass of the excess reactant will be left over?

HNO_3 L.R.

$$\#g\ Cu\ used = 225g\ HNO_3 \times \frac{1 mol}{63.01g} \times \frac{3\ Cu}{8\ HNO_3} \times \frac{63.55g}{1 mol} = 85.098g\ used$$

$$\#g\ Excess\ Cu = 87.0g - 85.098g = \boxed{1.9019\ g\ excess\ Cu}$$

3. What volume of CO_2 at STP can be made when 0.0250L of pentane (C_5H_{12}) (Density = 626.0g/L) is reacted with 40.0L of oxygen at STP?

$$C_5H_{12}(l) + 8O_2 \rightarrow 5CO_2 + 6H_2O$$

$$\#L\ CO_2 = 0.0250\ L\ C_5H_{12} \times \frac{626g}{1L} \times \frac{1 mol}{72.15g} \times \frac{5\ CO_2}{C_5H_{12}} \times \frac{22.4L}{1 mol} = \boxed{24.29L\ CO_2}$$

$$\#L\ CO_2 = 40.0L\ O_2 \times \frac{1 mol}{22.4L} \times \frac{5\ CO_2}{8\ O_2} \times \frac{22.4L}{1 mol} = 25L\ CO_2$$

4. If 50.0mL of 0.100M HCl is allowed to react with 30.0mL of 0.200M NaOH, which reagent is in excess?

$$\underset{LR}{HCl} + \underset{excess}{NaOH} \rightarrow NaCl + H_2O$$

$$\#g\ H_2O = \frac{0.100 mol}{L} \times 0.050\ L\ HCl \times \frac{H_2O}{HCl} \times \frac{18.02g}{1 mol} = 0.0901g$$

$$\#g\ H_2O = \frac{0.200 mol}{L} \times 0.030L\ NaOH \times \frac{H_2O}{NaOH} \times \frac{18.02g}{1 mol} = 0.216g$$

5. If 0.250g of $Ba(OH)_2$ is combined with 15.0mL of HBr(g) at 12.0C and 860mmHg, what mass of $BaBr_2(s)$ can be formed?

* Note R for mmHg used

$n = \frac{PV}{RT}$

$$1Ba(OH)_2 + 2HBr \rightarrow 1BaBr_2 + 2H_2O$$

$$\#g\ BaBr_2 = 0.250g\ Ba(OH)_2 \times \frac{1 mol}{171.34g} \times \frac{1 BaBr_2}{1 Ba(OH)_2} \times \frac{297.14g}{1 mol} = 0.4336g\ BaBr_2$$

$$\#g\ BaBr_2 = \frac{(860)(0.015)}{(62.364)(285)} \times \frac{1 BaBr_2}{2\ HBr} \times \frac{297.14g}{1 mol} = \boxed{0.1013\ g\ BaBr_2}$$

20–D2.3k define theoretical yields and actual yields

Students will:
20–D1.1s formulate questions about observed relationships and plan investigations of questions, ideas, problems and issues
• plan and predict states, products and theoretical yields for chemical reactions
• design an experiment to identify an ion; e.g., precipitation, flame test
• describe procedures for the safe handling, storage and disposal of materials used in the laboratory, with reference to WHMIS and consumer product labelling information

Students will:
20–D1.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions
• interpret stoichiometric ratios from chemical reaction equations
• perform calculations to determine theoretical yields
• use appropriate SI notation, fundamental and derived units and significant digits when performing stoichiometric calculations

20–D2.4k explain the discrepancy between theoretical and actual yields

1. Consider the reaction $I_2O_5(g) + 5\ CO(g)$ -------> $5\ CO_2(g) + I_2(g)$
a) 80.0 grams of iodine(V) oxide, I_2O_5, reacts with 28.0 grams of carbon monoxide, CO. Determine the mass of iodine I_2, which could be produced?

$$\#g\ I_2 = \frac{80.0g}{I_2O_5} \times \frac{1\,mol}{333.81g} \times \frac{I_2}{I_2O_5} \times \frac{253.81g}{1\,mol} = 60.83g\ I_2$$

$$\#g\ I_2 = \frac{28g}{CO} \times \frac{1\,mol}{28.01g} \times \frac{I_2}{5\,CO} \times \frac{253.81g}{1\,mol} = \boxed{50.74g\ I_2}$$

b) If, in the above situation, only 0.160 moles, of iodine, I_2 was produced.
i) what mass of iodine was produced?

$$\#g\ I_2 = 0.160\,mol \times \frac{253.81g}{mol} = \boxed{40.6096g\ I_2}$$

ii) what percentage yield of iodine was produced.

$$\%\ Yield = \frac{40.6096}{50.74} \times 100\% = \boxed{80.03\%}$$

2. A research supervisor told a chemist to make 100 g of chlorobenzene from the reaction of benzene with chlorine and to expect a yield no higher that 65%. What is the minimum quantity of benzene that can give 100 g of chlorobenzene if the yield is 65%? The equation for the reaction is:

$$C_6H_6 + Cl_2 \rightarrow C_6H_5Cl + HCl$$

benzene chlorobenzene

$$\#g\ Benzene = \frac{100g}{chloro} \times \frac{1mol}{112.56g} \times \frac{1\,C_6H_6}{1\,C_6H_5Cl} \times \frac{78.11g}{1\,mol} = 69.394g$$

expected if 100%

$$\%\ Yield = \frac{expected}{required}$$

$$\#g\ required = \frac{69.394g}{0.65} = $$

106.76 g Benzene Required if only 65% yield

3. Certain salts of benzoic acid have been used as food additives for decades. The potassium salt of benzoic acid, potassium benzoate, can be made by the action of potassium permanganate on toluene.

$C_7H_8 + 2\ KMnO_4 \rightarrow KC_7H_5O_2 + 2\ MnO_2 + KOH + H_2O$
toluene potassium benzoate

If the yield of potassium benzoate cannot realistically be expected to be more than 68%, what is the minimum number of grams of toluene needed to achieve this yield while producing 10.0 g of $KC_7H_5O_2$?

$\# g\ toluene = 10g\ KC_7H_5O_2 \times \frac{1\ mol}{160.2117\ g} \times \frac{1\ toluene}{1\ KC_7H_5O_2} \times \frac{92.14g}{1\ mol} = 5.75g$

$\# g\ Required = \frac{5.75}{0.68} =$ 8.458 g toluene required

4. Dimethylhydrazine, $(CH_3)_2NNH_2$, was used as a fuel for the Apollo Lunar Descent Module, with N_2O_4 being used as the oxidant. The products of the reaction are H_2O, N_2, and CO_2.
a) Write a balanced chemical equation for the combustion reaction.

$1(CH_3)_2NNH_2 + 2N_2O_4 \rightarrow 4H_2O + 3N_2 + 2CO_2$

b) If 150 kg of $(CH_3)_2NNH_2$ react with 460 kg of N_2O_4, what is the theoretical yield of N_2?

$\# g\ N_2 = 150000\ g \times \frac{1\ mol}{60.12\ g} \times \frac{3\ N_2}{1 (CH_3)_2NNH_2} \times \frac{28.02\ g}{1\ mol} =$ 209730.54g

$\# g\ N_2 = 460000\ g \times \frac{1\ mol}{92.02\ g} \times \frac{3\ N_2}{2\ N_2O_4} \times \frac{28.02\ g}{1\ mol} = 210104.33\ g$

c) If a 30 kg yield of N_2 gas represents a 68% yield, what mass of N_2O_4 would have been used up in the reaction?

solve for Required

$\# g\ N_2O_4 = 30000\ g\ N_2 \times \frac{1\ mol}{28.02\ g} \times \frac{2\ N_2O_4}{3\ N_2} \times \frac{92.02\ g}{1\ mol} = 65681.66\ g$ used N_2O_4 if 100% Yield

$\# g\ N_2O_4\ actual = 65681.66\ g \div 0.68 =$ 96590.67 g N_2O_4

20–D2.5k draw and interpret titration curves, using data from titration experiments involving strong monoprotic acids and strong monoprotic bases

20–D2.6k describe the function and choice of indicators in titrations

20–D2.7k identify equivalence points on strong monoprotic acid–strong monoprotic base titration curves and differentiate between the indicator end point and the equivalence point.

Results of 20.0mL of potassium hydroxide titrated with 2.2M HCl solution

	Trial 1	~~Trial 2~~	Trial 3	Trial 4
Initial Buret Reading	0.10mL	~~6.43mL~~	13.81mL	20.12mL
Final Buret Reading	6.43mL	~~13.81mL~~	20.12mL	26.40mL
	6.33	7.38	6.31	6.28

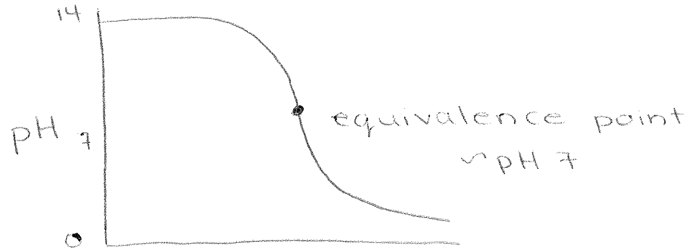
Determine the average volume of HCl used in the titration

6.3067 mL HCl

Determine the concentration of the unknown potassium hydroxide $KOH + HCl \rightarrow KCl + H_2O$

$\# \frac{mol}{L} KOH = \frac{2.2\ mol}{L} \times 0.0063067\ L \times \frac{KOH}{HCl} \times \frac{1}{0.02\ L} =$ 0.6937 M KOH

Draw and label a titration curve for the titration described.

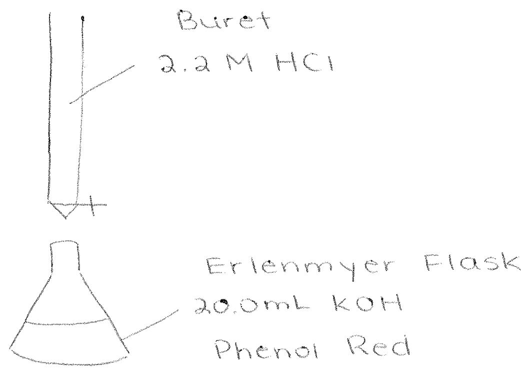


Determine an appropriate indicator to use in this titration and explain your choice.

Phenol Red.

Completely draw and label a titration set up for the lab described above. Include appropriate titles in your diagram

Figure 1: Titration Set Up of 20.0mL of KOH with HCl (2.2 $\frac{mol}{L}$)



Students will:
20–D2.1sts explain that scientific knowledge may lead to the development of new technologies, and new technologies may lead to or facilitate scientific discovery
• describe how industries apply principles of stoichiometry to minimize waste and maximize yield

20–D2.2sts explain how the appropriateness, risks and benefits of technologies need to be assessed for each potential application from a variety of perspectives, including sustainability
• assess the significance of specific by-products from industrial, commercial and household chemical reactions
• analyze the use of technologies, such as smokestacks and catalytic converters, to reduce emissions that are harmful to the environment, such as SO2(g) and greenhouse gases.

Students will:
20–D1.4s work collaboratively in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results
• use integrated software effectively and efficiently to incorporate data and text