Recitation Worksheet Five

Name: Key UGA ID:

Textbook:
Chemistry & Chemical Reactivity
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Instructions:

- This recitation worksheet covers Ch. 4.2-4.5, 4.7.
- Please enter your first and last name as it appears on the eLC roster (do not use a nickname that is not reflected in eLC).
- Your UGA myID is a combination of letters and numbers (example: Dr. Seivert's MyID is mds73312). **Do not use your 81x number**.
- Your completed worksheet has to be submitted to **Gradescope**. You have multiple options for submission:
  - You may use an app to annotate the worksheet by placing your answers in the answer boxes and showing your work when appropriate. Afterward, submit the worksheet to Gradescope. You will not need to upload anything to eLC.
  - You may print out the worksheet, write your answers in the answer boxes, and show your work on it when appropriate. Afterward, convert the worksheet to a PDF and submit to Gradescope. You will not need to upload anything to eLC.
  - If you do not have access to a printer, you may type your answers directly into the worksheet PDF and then submit it to Gradescope. Write your work on separate sheets of paper, convert them to a PDF, and upload to the appropriate dropbox on eLC.
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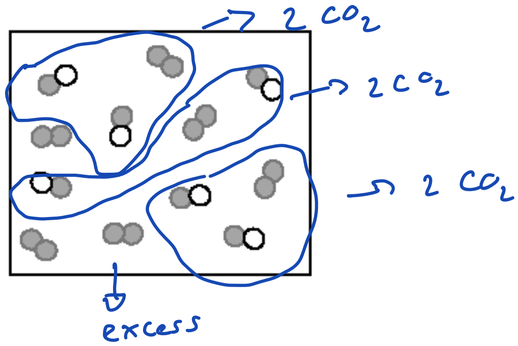
- The following criteria **must** be met to be eligible for full credit:
  - You must make sure the pages are in the correct order and have the same layout as the original worksheet when submitting to Gradescope regardless of your submission type.
  - Answers must be written in the corresponding answer boxes.
  - You must show your work when appropriate.
- This worksheet is due no later than **9:00 AM on the Saturday of the recitation week.**
- A periodic table and formula sheet are attached to the end of this worksheet. Please keep these attached to your worksheet in the correct order when submitting to Gradescope.

1. Carbon monoxide reacts with oxygen to produce carbon dioxide according to the chemical equation:

$$2\ CO\ (g) + O_2\ (g) \rightarrow 2\ CO_2\ (g)$$

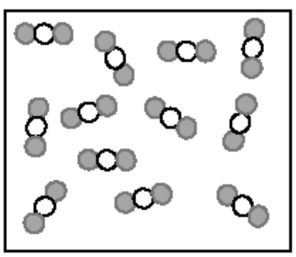
Given the initial reaction mixture shown in the figure (grey spheres represent oxygen and whites sphere represent carbon), which figure best represents the mixture after the reaction has ended?



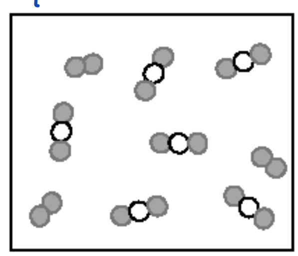
B

3 molecules O2 (excess)
6 molecules CO2 (formed)

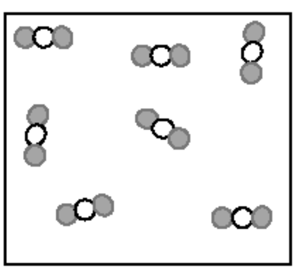
A.



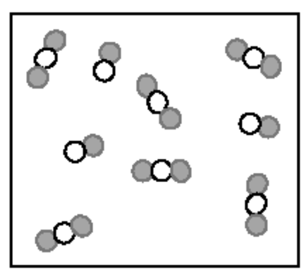
B.



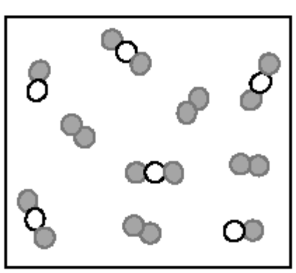
C.



D.



E.



2. First, balance the equation below, then answer the following questions in which 20.00 grams of explosive sodium metal and 20.00 grams of poisonous chlorine gas produces sodium chloride. Report your answers in **standard notation**.

$\underline{\ 2\ }$ Na (s) + $\underline{\ 1\ }$ Cl_2 (g) → $\underline{\ 2\ }$ NaCl (s)

(a) What is the limiting reactant?

B

A. Na
B. Cl_2 (circled)
C. Both Na and Cl_2

$$20.00\ g\ Na \left(\frac{mol}{22.99\ g}\ Na\right)\left(\frac{2\ mol\ NaCl}{2\ mol\ Na}\right)\left(\frac{58.44\ g}{mol}\ NaCl\right) = 50.8395\ g$$

$$20.00\ g\ Cl_2 \left(\frac{mol}{70.90\ g}\ Cl_2\right)\left(\frac{2\ mol\ NaCl}{1\ mol\ Cl_2}\right)\left(\frac{58.44\ g}{mol}\ NaCl\right) = 32.9704\ g$$

(b) What mass (in grams) of NaCl forms if the percent yield is 100.0%?

32.97

g (above)

(c) What mass (in grams) of NaCl forms if the percent yield is 74.1%?

24.4

g

$$\%\ yield = \frac{actual}{theoretical}$$

$$0.741 = \frac{actual}{32.9704\ g} \rightarrow 24.4310\ g$$

(d) What is the percent yield of the reaction if 23.51 grams of NaCl is collected?

71.31

%

$$\frac{23.51\ g}{32.9704\ g} \times 100$$

$C_3H_7OH \rightarrow d = m/V \rightarrow 0.804\ g/mL = m/6.67\ mL \rightarrow m = 5.36268\ g$

$H_2O \rightarrow d = m/V \rightarrow 1.00\ g/mL = m/2.45\ mL \rightarrow m = 2.45\ g$

3. Consider the balanced combustion reaction below in which 6.67 mL C_3H_7OH (d = 0.804 g/cm^3) reacts in the presence of 9.04 g O_2 gas yielding 2.45 mL of H_2O (density = 1.00 g/cm^3). Report your answers in **standard notation**.

$$2\ C_3H_7OH\ (l) + 9\ O_2\ (g) \rightarrow 6\ CO_2 + 8\ H_2O$$

(a) What is the limiting reactant?

B

A. C_3H_7OH
B. O_2

$$5.36268\ g\ C_3H_7OH \left(\frac{mol}{60.11\ g}\right)\left(\frac{8\ mol\ H_2O}{2\ mol\ C_3H_7OH}\right)\left(\frac{18.02\ g\ H_2O}{mol}\right) = 6.4306\ g$$

$$9.04\ g\ O_2 \left(\frac{mol}{32\ g}\right)\left(\frac{8\ mol\ H_2O}{9\ mol\ O_2}\right)\left(\frac{18.02\ g\ H_2O}{mol}\right) = 4.5250\ g$$

(b) What is the theoretical yield of H_2O (in grams)?

4.53

g

(c) What is the percent yield of H_2O?

$$\frac{2.45\ g}{4.5250\ g} \times 100$$

54.1

%

4. A scientist goes to lab to synthesize Na_3AlF_6 via the balanced chemical reaction below. If they need 780. grams of Na_3AlF_6, and the overall percent yield is 45.4 %, how much Al_2O_3 (in grams) is needed? You may assume NaOH and HF is in excess here. Report your answer in **standard notation**. actual yield

$$6\ NaOH + Al_2O_3 + 12\ HF \rightarrow 2\ Na_3AlF_6 + 9\ H_2O$$

417

g

$$0.454 = \frac{780.}{theor.} \rightarrow 1.71806e3\ g\ Na_3AlF_6$$

$$1.71806e3\ g\ Na_3AlF_6 \left(\frac{mol}{209.95\ g}\right)\left(\frac{1\ mol\ Al_2O_3}{2\ mol\ Na_3AlF_6}\right)\left(\frac{101.96\ g\ Al_2O_3}{mol}\right)$$

$$= 417.175\ g$$

5. Consider the balanced equation below in which 10.86 grams of PCl_5 reacts with 13.58 grams of AsF_3.

$$3\ PCl_5 + 5\ AsF_3 \rightarrow 3\ PF_5 + 5\ AsCl_3$$

(a) What is the **excess** reactant?

B

A. PCl_5
B. AsF_3

(b) How many grams of **excess** reactant are left over after the reaction is complete? Report your answer in **standard notation** and with **four significant figures**.

2.113

g

$10.86\ g\ PCl_5 \left(\frac{mol}{208.22\ g}\right)\left(\frac{3\ mol\ PF_5}{3\ mol\ PCl_5}\right)\left(\frac{125.97\ g\ PF_5}{mol}\right) = 6.57014\ g$

↳ limiting

$13.58\ g\ AsF_3 \left(\frac{mol}{131.92\ g}\right)\left(\frac{3\ mol\ PF_5}{5\ mol\ AsF_3}\right)\left(\frac{125.97\ g\ PF_5}{mol}\right) = 7.7805\ g$

↳ excess

$7.7805\ g - 6.57014\ g = 1.21036\ g\ PF_5$

$1.21036\ g\ PF_5 \left(\frac{mol}{125.97\ g}\right)\left(\frac{5\ mol\ AsF_3}{3\ mol\ PF_5}\right)\left(\frac{131.92\ g\ AsF_3}{mol}\right) = 2.113\ g$

or

$6.57014\ g\ PF_5 \times \left(\frac{mol}{125.97\ g}\right)\left(\frac{5\ mol\ AsF_3}{3\ mol\ PF_5}\right)\left(\frac{131.92\ g\ AsF_3}{mol}\right) = 11.467451\ g$

$13.58\ g - 11.467451\ g = 2.113\ g$

* either approach is okay

6. In combustion analysis, the oxygen content of a substance is equal to the total oxygen in the CO_2 and H_2O collected in the absorbers.

B

$C_xH_yO_z + O_2 \rightarrow CO_2 + H_2O$

A. True
B. False

7. Write the chemical equation for the combustion of butanoic acid ($C_4H_8O_2$) and determine which statements are **true**. Select any that apply and answer using capital letters with no spaces (e.g. ABCDE).

AE

A. Combusting 1 mole of butanoic acid produces 4 moles of water
B. Carbon monoxide and water are the two products of this reaction
C. The sum of the stoichiometric coefficients on the balanced chemical equation is 13
D. The total number of moles on the product's side is equal to the total number of moles on the reactant's side
E. To react 5 moles of oxygen, 1 mol of butanoic acid is required

$C_4H_8O_2\,(l) + 5\,O_2\,(g) \rightarrow 4\,CO_2\,(g) + 4\,H_2O\,(g)$

8. Consider an unknown organic compound composed of carbon, oxygen, and hydrogen. A 10.00 g sample of this compound is burned completely in the presence of excess oxygen in which 16.94 g of carbon dioxide and 6.930 g of water are isolated.

Provide an empirical formula for this compound. Answer by listing the chemical formula with the carbon first, then hydrogen, then oxygen (e.g. $C_xH_yO_z$).

$C_4H_8O_3$

The molar mass of this compound is 104.12 g/mol. Provide the molecular formula listing the formula with the carbon first, then hydrogen, then oxygen (e.g. $C_xH_yO_z$).

$C_4H_8O_3$

$$16.94 \text{ g } CO_2 \times \left(\frac{\text{mol}}{44.01 \text{ g } CO_2}\right) \times \left(\frac{1 \text{ mol C}}{1 \text{ mol } CO_2}\right) = 0.38491252 \text{ mol C}$$

$$6.930 \text{ g } H_2O \times \left(\frac{\text{mol}}{18.02 \text{ g } H_2O}\right) \times \left(\frac{2 \text{ mol H}}{1 \text{ mol } H_2O}\right) = 0.76914539 \text{ mol H}$$

$$0.38491252 \text{ mol C} \times \left(\frac{12.01 \text{ g C}}{\text{mol}}\right) = 4.622799364 \text{ g C}$$

$$0.76914539 \text{ mol H} \times \left(\frac{1.01 \text{ g H}}{\text{mol}}\right) = 0.7768368 \text{ g H}$$

$$10.00 \text{ g total (C, H, O)} - 4.622799364 \text{ g C} - 0.7768368 \text{ g H} = 4.6003638 \text{ g O}$$

$$4.6003638 \text{ g O} \times \left(\frac{\text{mol}}{16 \text{ g}}\right) = 0.2875227 \text{ mol O}$$

$0.38491252 \text{ mol C} / 0.2875227 \text{ mol O} = 1.3387203 \times 3 = 4$

$0.76914539 \text{ mol H} / 0.2875227 \text{ mol O} = 2.6750768 \times 3 = 8$

$0.2875227 \text{ mol O} / 0.2875227 \text{ mol O} = 1 \times 3 = 3$

$C_4H_8O_3$

↓

MM = 104.12 g/mol

↓

empirical and molecular

9. What mass (g) of NaOH is contained in 250.0 mL of a 0.400 M sodium hydroxide solution? Report your answer in **standard notation**.

4.00

g

$M = \frac{mol}{L} \rightarrow 0.400\ M = \frac{mol}{0.2500\ L} \rightarrow 0.100\ mol\ NaOH$

$0.100\ mol\ NaOH \times \left(\frac{40.00\ g}{mol}\right) = 4.00\ g\ NaOH$

10. Concentrated hydrochloric acid is approximately 12.2 M. If a student needs to prepare 300. mL of 1.500 M hydrochloric acid, what volume (mL) of concentrated acid is needed? Report your answer in **standard notation**.

36.9

mL

$M_1 V_1 = M_2 V_2$

$(12.2\ M)(V_1) = (1.500\ M)(300.\ mL)$

11. What is the molarity of the **chloride ions** in a 600. mL solution after 127.4 g of aluminum chloride (molar mass = 133.33 g/mol) has been added? Report your answer in **standard notation**.

$AlCl_{3(s)} \xrightarrow{H_2O} Al^{3+}_{(aq)} + 3Cl^-_{(aq)}$

4.78

$127.4\ g\ AlCl_3 \times \left(\frac{mol}{133.33\ g}\right) = 0.9555239\ mol\ AlCl_3$

$M = \frac{mol}{L} = \frac{0.9555239\ mol\ AlCl_3}{0.600\ L} = 1.5925398\ M\ AlCl_3$

$\frac{1.5925398\ mol\ AlCl_3}{L} \times \frac{3\ mol\ Cl^-}{1\ mol\ AlCl_3} = 4.78\ M\ Cl^-$

12. Consider a hypothetical set of experiments completed by a student in lab given below. Answer the following questions using **standard notation**.

(a) The student starts by dissolving 7.24 × 10^3 milligrams of NaCl in 150.00 mL deionized water inside a volumetric flask. What is the concentration of NaCl in the flask?

[NaCl] : | 0.826 | M

$$\frac{7.24e3\ mg\left(\frac{1\ g}{1000\ mg}\right)\left(\frac{mol}{58.44\ g}\right)}{150.00\ mL\left(\frac{1\ L}{1000\ mL}\right)} = 0.825918321\ M$$

(b) In a separate flask, the student dissolves 3.79 × 10^{-2} kilograms of LiBr in 200.00 mL deionized water. What is the concentration of LiBr in the flask?

[LiBr] : | 2.18 | M

$$\frac{3.79e\text{-}2\ kg\left(\frac{1000}{1\ kg}\right)\left(\frac{mol}{86.84\ g}\right)}{200.00\ mL\left(\frac{1\ L}{1000\ mL}\right)}$$

$= 2.1821741\ M$

(c) After making both solutions, the student places 100.00 mL of the NaCl solution and 100.00 mL of the LiBr solution in a separate volumetric flask together. What are the final concentrations of both solutions after mixing them together?

[NaCl] : | 0.413 | M

[LiBr] : | 1.09 | M

$M_1 V_1 = M_2 V_2$

NaCl: $(100.00\ mL)(0.826\ M) = (200.00\ mL)(M_2)$

LiBr: $(100.00\ mL)(2.18\ M) = (200.00\ mL)(M_2)$

$BaCl_{2(aq)} + 2AgNO_{3(aq)} \rightarrow 2AgCl_{(s)} + Ba(NO_3)_{2(aq)}$

13. If 70.00 mL of 0.910 M $BaCl_2$ is added to 45.20 mL of 0.190 M $AgNO_3$, and 0.785 grams of solid is collected, what is the percent yield of the reaction? Report your answer in **standard notation**.

63.8	%

$\frac{0.910 \text{ mol}}{L} BaCl_2 (70.00 \text{ mL}/1000 \text{ mL}) L \left(\frac{2 \text{ mol } AgCl}{1 \text{ mol } BaCl_2}\right)\left(\frac{143.32 \text{ g}}{\text{mol}} AgCl\right)$

$= 18.25897$ g AgCl

limiting

$\frac{0.190 \text{ mol}}{L} AgNO_3 (45.20 \text{ mL}/1000 \text{ mL}) L \left(\frac{2 \text{ mol } AgCl}{2 \text{ mol } AgNO_3}\right)\left(\frac{143.32 \text{ g}}{\text{mol}} AgCl\right)$

$= 1.230832$ g AgCl

$(0.785 \text{ g} / 1.230832 \text{ g}) \times 100 = 63.77799$ %

14. Consider a hypothetical scenario in which you need 125.0 grams of $PbCl_2$. You go to the lab and find a limited volume of 0.700 M NaCl and an excessive amount of 0.900 M $Pb(NO_3)_2$, both of which can be combined to form $PbCl_2$. If the percent yield of the reaction is 51.25 %, what volume (in mL) of 0.700 M NaCl do you need? Hint: $Pb(NO_3)_2$ will be your excess reactant. Report your answer in **scientific notation**.

2.51×10^{3} mL

$Pb(NO_3)_{2(aq)} + 2NaCl_{(aq)} \rightarrow PbCl_{2(s)} + 2NaNO_{3(aq)}$

$\frac{125.0 \text{ g}}{x} = 0.5125 \rightarrow 243.902439$ g $PbCl_2$

$243.902439 \text{ g } PbCl_2 \left(\frac{\text{mol}}{278.1 \text{ g}} PbCl_2\right)\left(\frac{2 \text{ mol NaCl}}{1 \text{ mol } PbCl_2}\right)\left(\frac{L}{0.700 \text{ mol}}\right) \times \left(\frac{1000 \text{ mL}}{1 \text{ L}}\right)$

$CsCl_{(aq)} + AgNO_{3\,(aq)} \rightarrow AgCl_{(s)} + CsNO_{3\,(aq)}$

15. A 375.00 mL sample of 0.400 M CsCl and a 200.00 mL sample of 1.900 M CsCl is added to a beaker. Afterwards, $AgNO_3$ is added to the beaker to react with the CsCl solution. Start by writing the balanced equation, and then determine the mass of $AgNO_3$ required to completely react with CsCl. Report your answer in **standard notation**.

90.0	g

$0.400\ M = \frac{mol}{0.37500\ L} \rightarrow 0.150\ mol\ CsCl$

$1.900\ M = \frac{mol}{0.20000\ L} \rightarrow 0.3800\ mol\ CsCl$

$0.150\ mol + 0.3800\ mol = 0.530\ mol\ CsCl$

$0.530\ mol\ CsCl \left(\frac{1\ mol\ AgNO_3}{1\ mol\ CsCl}\right)\left(\frac{169.88\ g}{mol}\ AgNO_3\right) = 90.0364\ g\ AgNO_3$

16. A scientist goes to the lab and finds a solution of H_3PO_4 that has an unknown concentration. Upon experimentation, they find that they can neutralize 60.00 mL of the H_3PO_4 solution by using 41.75 mL of a 2.000 M LiOH solution. Based on this information, what is the concentration of the unknown H_3PO_4 solution? Report your answer in **standard notation**.

$$H_3PO_4\ (aq) + 3\ LiOH\ (aq) \rightarrow Li_3PO_4\ (aq) + 3\ H_2O\ (l)$$

0.4639	M

$(0.04175\ L\ LiOH)\left(\frac{2.000\ mol}{L}\ LiOH\right)\left(\frac{1\ mol\ H_3PO_4}{3\ mol\ LiOH}\right)$

$= 0.02783333\ mol\ H_3PO_4$

$M = \frac{0.02783333\ mol\ H_3PO_4}{(60.00\ mL/1000\ mL)\ L}$

17. A beaker containing 100.00 mL of 1.50 M KOH is mixed with another beaker containing 200.00 mL of 2.00 M $HClO_4$. What are the concentrations of the ions given below after the reaction goes to completion? Report your answers in **standard notation** and to **three significant figures**.

I. Perchlorate ion: 1.33 M

II. Hydroxide ion: 0.00 M

III. Potassium ion: 0.500 M

IV. Hydrogen ion: 0.833 M

$KOH_{(aq)} + HClO_{4\,(aq)} \rightarrow KClO_{4\,(aq)} + H_2O_{(l)}$

total: $K^+_{(aq)} + OH^-_{(aq)} + H^+_{(aq)} + ClO_4^-{}_{(aq)} \rightarrow K^+_{(aq)} + ClO_4^-{}_{(aq)} + H_2O_{(l)}$

net: $H^+_{(aq)} + OH^-_{(aq)} \rightarrow H_2O_{(l)}$

Spectators: K^+, ClO_4^-

For KOH, $M = \frac{mol}{L} \rightarrow 1.50\ M = \frac{mol}{0.10000\ L} \rightarrow 0.150\ mol$

For $HClO_4$, $M = \frac{mol}{L} \rightarrow 2.00\ M = \frac{mol}{0.20000\ L} \rightarrow 0.400\ mol$

$0.150\ mol\ KOH \times \left(\frac{1\ mol\ KClO_4}{1\ mol\ KOH}\right) = 0.150\ mol\ KClO_4$

↳ limiting

$0.400\ mol\ HClO_4 \times \left(\frac{1\ mol\ KClO_4}{1\ mol\ HClO_4}\right) = 0.400\ mol\ KClO_4$

↳ excess

For OH^-, limiting reactant, not spectator, so... $[OH^-] = 0.00\ M$

for ClO_4^-, this is a spectator ion...

$$M_1V_1 = M_2V_2$$

$$(2.00\ M)(200.00\ mL) = (M_2)(300.00\ mL)$$

$$M_2 = 1.333\underline{3}\ M\ HClO_4$$

$$1.333\underline{3}\ M\ HClO_4 \times \left(\frac{1\ mol\ ClO_4^-}{1\ mol\ HClO_4}\right) = \boxed{1.33\ M\ ClO_4^-}$$

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for K^+, this is also a spectator ion...

$$M_1V_1 = M_2V_2$$

$$(1.50\ M)(100.00\ mL) = (M_2)(300.00\ mL)$$

$$M_2 = 0.50\underline{0}\ M\ KOH$$

$$0.50\underline{0}\ M\ KOH \times \left(\frac{1\ mol\ K^+}{1\ mol\ KOH}\right) = \boxed{0.500\ M\ K^+}$$

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for H^+, excess reactant, not spectator...

from prev. page:

$$0.15\underline{0}\ mol\ KOH \times \left(\frac{1\ mol\ KClO_4}{1\ mol\ KOH}\right) = 0.150\ mol\ KClO_4$$

↳ limiting

$$0.40\underline{0}\ mol\ HClO_4 \times \left(\frac{1\ mol\ KClO_4}{1\ mol\ HClO_4}\right) = 0.900\ mol\ KClO_4$$

↳ excess

solve for excess reactant amount:

$$0.400\ mol - 0.150\ mol = 0.250\ mol\ KClO_4$$

$$0.250\ mol\ KClO_4 \times \left(\frac{1\ mol\ HClO_4}{1\ mol\ KClO_4}\right) = 0.250\ mol\ HClO_4$$

$$[HClO_4] = \frac{0.250\ mol\ HClO_4}{0.10000\ L + 0.20000\ L} = 0.83\underline{3}33\ M\ HClO_4$$

$$0.83\underline{3}33\ M\ HClO_4 \times \left(\frac{1\ mol\ H^+}{1\ mol\ HClO_4}\right) = \boxed{0.833\ M\ H^+}$$

Extra Practice Questions: these questions will not be graded.

1. First, balance the equation below, then determine the limiting reactant in the following scenario. Write the corresponding letter ("A" or "B") in the box below.

1 P_4 (s) + 6 Cl_2 (g) → 4 PCl_3 (l)

(A) 6 mol P_4 reacting with (B) 6 mol Cl_2

B

$$6 \text{ mol } P_4 \left(\frac{4 \text{ mol } PCl_3}{1 \text{ mol } P_4} \right) = 24 \text{ mol } PCl_3$$

$$6 \text{ mol } Cl_2 \left(\frac{4 \text{ mol } PCl_3}{6 \text{ mol } Cl_2} \right) = 4 \text{ mol } PCl_3$$

2. How many grams of excess reactant remain when 10.00 g of iron(**III**) oxide react with 15.00 g of elemental aluminum (to completion) to create aluminum oxide and elemental iron? Report your answer in **standard notation** and **four significant figures**.

11.62 g

$$Fe_2O_3 (s) + 2Al (s) \rightarrow Al_2O_3 (s) + 2Fe (s)$$

$$10.00 \text{ g } Fe_2O_3 \times \left(\frac{\text{mol}}{159.7 \text{ g}} \right) \times \left(\frac{1 \text{ mol } Al_2O_3}{1 \text{ mol } Fe_2O_3} \right) \times \left(\frac{101.96 \text{ g } Al_2O_3}{\text{mol}} \right) = 6.384471 \text{ g } Al_2O_3$$

$$15.00 \text{ g } Al \times \left(\frac{\text{mol}}{26.98 \text{ g}} \right) \times \left(\frac{1 \text{ mol } Al_2O_3}{2 \text{ mol } Al} \right) \times \left(\frac{101.96 \text{ g } Al_2O_3}{\text{mol}} \right) = 28.34322 \text{ g } Al_2O_3$$

cont. on next page...

$28.34322\ g - 6.384471\ g = 21.95875\ g\ Al_2O_3$

$$21.95875\ g\ Al_2O_3 \times \left(\frac{mol}{101.96\ g}\right) \times \left(\frac{2\ mol\ Al}{1\ mol\ Al_2O_3}\right) \times \left(\frac{26.98\ g\ Al}{mol}\right)$$

$$= \boxed{11.62\ g\ Al}$$

or

$$6.384471\ g\ Al_2O_3 \times \left(\frac{mol}{101.96\ g}\right) \times \left(\frac{2\ mol\ Al}{1\ mol\ Al_2O_3}\right) \times \left(\frac{26.98\ g\ Al}{mol}\right)$$

$$= 3.378835\ g\ Al$$

$$15.00\ g - 3.378835\ g = \boxed{11.62\ g}$$

* either approach is okay

3. How many grams of K_2O (MW = 94.20 g/mol) are formed when 150.0 g of KNO_3 (MW = 101.11 g/mol) is decomposed according to the balanced reaction below if the percent yield is 58.15 %?

$$4\ KNO_3\ (s) \rightarrow 2\ K_2O\ (s) + 2\ N_2\ (g) + 5\ O_2\ (g)$$

C

$150.0\ g\ KNO_3 \times \left(\frac{mol}{101.11\ g}\right) \times \left(\frac{2\ mol\ K_2O}{4\ mol\ KNO_3}\right) \times \left(\frac{94.20\ g}{mol}\right) \times (0.5815)$

A. 279.4 g
B. 69.87 g
C. 40.63 g
D. 75.00 g
E. 162.5 g

4. A scientist goes to lab and decomposes a 25.0 g sample of $PbCO_3$ into PbO and CO_2 according to the balanced equation below. What is the percent yield of this reaction if 12.0 g of PbO is collected? (Molar mass $PbCO_3$ = 267.21 g/mol, molar mass PbO = 223.20 g/mol, molar mass CO_2 = 44.01 g/mol)

$$PbCO_3\ (s) \rightarrow PbO\ (s) + CO_2\ (g)$$

C

$25.0\ g\ PbCO_3 \times \left(\frac{mol}{267.21\ g}\right) \times \left(\frac{1\ mol\ PbO}{1\ mol\ PbCO_3}\right) \times \left(\frac{223.20\ g}{mol}\right)$

$= 20.882452\ g\ PbO$

A. 34.3 %
B. 48.0 %
C. 57.5 %
D. 71.2 %
E. 89.9 %

$\%\ yield = \frac{12.0\ g}{20.882452\ g} \times 100$

5. Glucose ($C_6H_{12}O_6$) can be combusted. Write the balanced combustion equation and select the coefficient for carbon dioxide.

E

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$

A. 2
B. 3
C. 4
D. 5
E. 6

6. Styrene, the building block of the plastic polystyrene (Styrofoam and #6 plastic), is a compound consisting only of C and H. You run combustion analysis on 4.21×10^{-3} moles of the compound and find that it produces 1.481 g of CO_2 and 0.303 g of H_2O.

I. What is the empirical formula of styrene? Answer by listing the chemical formula with the carbon first and then hydrogen (e.g. C_xH_y).

CH

II. What is the molecular formula of styrene if the molar mass is 104.16 g/mol? Answer by listing the chemical formula with the carbon first and then hydrogen (e.g. C_xH_y).

C_8H_8

$1.481\text{ g }CO_2 \times \left(\frac{\text{mol}}{44.01\text{ g}}CO_2\right) \times \left(\frac{1\text{ mol C}}{1\text{ mol }CO_2}\right) = 0.033651\underline{4}\text{ mol C}$

$0.303\text{ g }H_2O \times \left(\frac{\text{mol}}{18.02\text{ g}}H_2O\right) \times \left(\frac{2\text{ mol H}}{1\text{ mol }H_2O}\right) = 0.03362\underline{9}3\text{ mol H}$

$0.033651\underline{4}\text{ mol C} / 0.03362\underline{9}3 = 1$

$0.03362\underline{9}3\text{ mol H} / 0.03362\underline{9}3 = 1$

$CH \rightarrow MM = 13.02\text{ g/mol}$

$\frac{104.16\text{ g/mol}}{13.02\text{ g/mol}} = 8 \rightarrow C_8H_8$

$K_3PO_4 \rightarrow 3K^+_{(aq)} + PO_4^{3-}_{(aq)}$

7. If 31.5 g of potassium phosphate is dissolved in 750. mL of water, what is the molarity of the **potassium ions** in the resulting solution? Report your answer in **standard notation**.

0.594	M

$$\frac{31.5\,g\,K_3PO_4\left(\frac{mol}{212.27\,g}\right)}{750.\,mL\left(\frac{1\,L}{1000\,mL}\right)} = 0.1978612\ M\ K_3PO_4$$

$[K^+] = 0.1978612\ M \times 3$

8. A student leaves 750. mL of a 50.0 mM salt solution in an uncorked flask, and it evaporates down to a volume of 699 mL before someone else finds it. What is the concentration (mM) of the resulting solution? Report your answer in **standard notation**.

53.6	mM

$M_1V_1 = M_2V_2$

$(50.0\ mM)(750.\ mL) = (M_2)(699\ mL)$

9. If 70. mL of a 0.29 M $Mg(OH)_2$ solution is diluted to a total volume of 250. mL, what is the final concentration (M) of the **hydroxide ions** in solution? Report your answer in **standard notation**.

0.16	M

$Mg(OH)_2 \rightarrow Mg^{2+}_{(aq)} + 2OH^-_{(aq)}$

$(70.\ mL)(0.29\ M) = M_2\ (250.\ mL)$

$M_2 = 0.0812\ M\ Mg(OH)_2$

$[OH^-] = 0.0812\ M \times 2 = 0.1624\ M$

10. Luria Broth (LB) is a widely used bacterial culture medium. Most recipes for LB are 40.% tryptone, 40.% sodium chloride, and 20.% yeast extract. 2.00 L of LB is made by dissolving 50. g of this mixture in 2.00 L of water. What is the molarity of the sodium chloride in the resulting solution? Report your answer in **standard notation**.

0.17	M

$50.\ g \times 0.40\ NaCl = 20.\ g\ NaCl$

$$\frac{20.\ g\ NaCl \times \left(\frac{mol}{58.44\ g}\right)}{2.00\ L}$$

11. Figure 1 shows a 10.0 mL sample taken from a solution of NaCl. Another 10.0mL sample was taken after a student left the solution unattended for a period of time, which is shown in Figure 2:

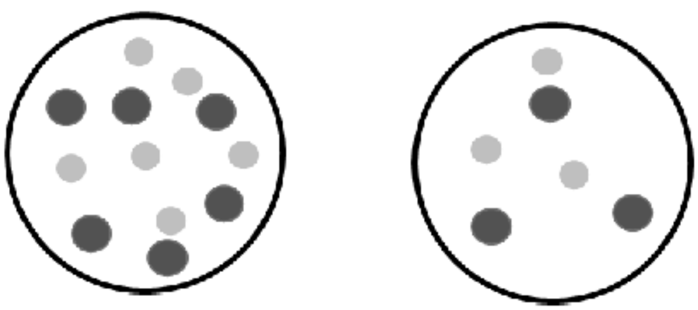

Figure 1 Figure 2

→ more dilute

What happened to the solution while it was unattended?

B

A. Water evaporated from the solution.
B. Water was added to the solution.
C. Sodium chloride solid was added to the solution.
D. More concentrated sodium chloride solution was added to the solution.
E. More than one of the above could have happened

12. What volume (in mL) of 7.90 M H_3PO_4 is produced when 3.25 metric tons of $Ca_5(PO_4)_3F$ reacts with excess H_2SO_4 and excess H_2O if the percent yield is 58.2%? Report your answer in **scientific notation**. Note: 1 metric ton = 1000 kg

$Ca_5(PO_4)_3F$ (s) + 5 H_2SO_4 (aq) + 10 H_2O (l) →
3 H_3PO_4 (aq) + 5 ($CaSO_4 \cdot 2\ H_2O$) (s) + HF (aq)

| 1.42 | × 10^ 6 | mL |

$\left(3.25 \text{ metric tons}\right)\left(\frac{1000 \text{ kg}}{1 \text{ metric ton}}\right)\left(\frac{1000 \text{ g}}{1 \text{ kg}}\right) Ca_5(PO_4)_3F \left(\frac{\text{mol}}{504.31 \text{ g}}\right)\left(\frac{3 \text{ mol } H_3PO_4}{1 \text{ mol } Ca_5(PO_4)_3F}\right)$

$= \left(1.93333e4 \text{ mol } H_3PO_4\right)\left(\frac{L}{7.90 \text{ mol } H_3PO_4}\right)\left(\frac{1000 \text{ mL}}{1 \text{ L}}\right)\left(0.582\right)$

13. A scientist is finishing up a reaction and is putting away their reagents. In the process, they accidentally knock over a bottle of 5.50 M H_2SO_4. To clean up the mess, they neutralize the acid using $NaHCO_3$, which is a common practice in the laboratory. If they spilled 135.51 mL of H_2SO_4, what mass (in grams) of $NaHCO_3$ will they need to completely neutralize the acid? Report your answer in **standard notation**.

H_2SO_4 (aq) + 2 $NaHCO_3$ (s) → Na_2SO_4 (aq) + 2 H_2O (l) + 2 CO_2 (g)

Disclaimer: it is also common practice in the laboratory to use an excessive amount of $NaHCO_3$ as quickly as possible to neutralize an acid spill due to safety concerns.

| 125 | g |

$0.13551 \text{ L}\left(\frac{5.50 \text{ mol}}{L}\right) H_2SO_4 \left(\frac{2 \text{ mol } NaHCO_3}{1 \text{ mol } H_2SO_4}\right)\left(\frac{84.01 \text{ g } NaHCO_3}{\text{mol}}\right)$

14. If 150. mL of 0.25 M calcium hydroxide and 750 mL of 0.160 M hydrobromic acid are mixed together, what are the concentrations of the ions given below after the reaction goes to completion? Report your answers in **standard notation** and to **two significant figures**.

I. Calcium ion: 0.042 M

II. Hydroxide ion: 0.0 M

III. Bromide ion: 0.13 M

IV. Hydrogen ion: 0.050 M

$Ca(OH)_2\,(aq) + 2HBr\,(aq) \rightarrow CaBr_2\,(aq) + 2H_2O\,(l)$

total: $Ca^{2+}(aq) + 2OH^-(aq) + 2H^+(aq) + 2Br^-(aq) \rightarrow Ca^{2+}(aq) + 2Br^-(aq) + 2H_2O\,(l)$

net: $H^+(aq) + OH^-(aq) \rightarrow H_2O\,(l)$

Spectators: Ca^{2+}, Br^-

For $Ca(OH)_2$: $0.25\ M = \frac{mol}{0.150\ L} \rightarrow 0.0375$ mol $Ca(OH)_2$

For HBr: $0.160\ M = \frac{mol}{0.75\ L} \rightarrow 0.12$ mol HBr

0.0375 mol $Ca(OH)_2 \times \left(\frac{1\ mol\ CaBr_2}{1\ mol\ Ca(OH)_2}\right) = 0.0375$ mol $CaBr_2$

↳ limiting

0.12 mol HBr $\times \left(\frac{1\ mol\ CaBr_2}{2\ mol\ HBr}\right) = 0.060$ mol $CaBr_2$

↳ excess

For OH^-, limiting reactant, not spectator, so... $[OH^-] = 0.0$ M for Ca^{2+}, this is a spectator ion...

$$M_1V_1 = M_2V_2$$

$$(0.25\ M)(0.150\ L) = (M_2)(0.900\ L)$$

$$M_2 = 0.0416667\ M\ Ca(OH)_2$$

$$\frac{0.0416667\ mol\ Ca(OH)_2}{L} \left| \frac{1\ mol\ Ca^{2+}}{1\ mol\ Ca(OH)_2} \right. = \boxed{0.042\ M\ Ca^{2+}}$$

---

for Br^-, this is a spectator ion...

$$M_1V_1 = M_2V_2$$

$$(0.160\ M)(0.75\ L) = (M_2)(0.900\ L)$$

$$M_2 = 0.133333\ M\ HBr$$

$$\frac{0.133333\ mol\ HBr}{L} \left| \frac{1\ mol\ Br^-}{1\ mol\ HBr} \right. = \boxed{0.13\ M\ Br^-}$$

---

for H^+, excess reactant, not spectator...

from prev. page:

$$0.0375\ mol\ Ca(OH)_2 \times \left(\frac{1\ mol\ CaBr_2}{1\ mol\ Ca(OH)_2} \right) = 0.0375\ mol\ CaBr_2$$

↳ limiting

$$0.12\ mol\ HBr \times \left(\frac{1\ mol\ CaBr_2}{2\ mol\ HBr} \right) = 0.060\ mol\ CaBr_2$$

↳ excess

Solve for excess reactant amount:

$$0.060\ mol - 0.0375\ mol = 0.0225\ mol\ CaBr_2$$

$$0.0225\ mol\ CaBr_2 \times \left(\frac{2\ mol\ HBr}{1\ mol\ CaBr_2} \right) = 0.045\ mol\ HBr$$

$$[HBr] = \frac{0.045\ mol\ HBr}{0.150\ L + 0.75\ L} = 0.050\ M\ HBr$$

$$\frac{0.050\ mol\ HBr}{L} \left| \frac{1\ mol\ H^+}{1\ mol\ HBr} \right. = \boxed{0.050\ M\ H^+}$$

Periodic Table of the Elements

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** 1.01																	2 **He** 4.00
3 **Li** 6.94	4 **Be** 9.01											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
11 **Na** 22.99	12 **Mg** 24.31											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.06	17 **Cl** 35.45	18 **Ar** 39.95
19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.87	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.38	31 **Ga** 69.72	32 **Ge** 72.63	33 **As** 74.92	34 **Se** 78.97	35 **Br** 79.90	36 **Kr** 83.80
37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.95	43 **Tc** [97]	44 **Ru** 101.07	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.76	52 **Te** 127.60	53 **I** 126.90	54 **Xe** 131.29
37 **Cs** 132.91	56 **Ba** 137.33		72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.84	75 **Re** 186.21	76 **Os** 190.23	77 **Ir** 192.22	78 **Pt** 195.08	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.38	82 **Pb** 207.2	83 **Bi** 208.98	84 **Po** [209]	85 **At** [210]	86 **Rn** [222]
87 **Fr** [223]	88 **Ra** [226]		104 **Rf** [267]	105 **Db** [268]	106 **Sg** [269]	107 **Bh** [270]	108 **Hs** [269]	109 **Mt** [277]	110 **Ds** [281]	111 **Rg** [282]	112 **Cn** [285]	113 **Nh** [286]	114 **Fl** [290]	115 **Mc** [290]	116 **Lv** [293]	117 **Ts** [294]	118 **Og** [294]

57 **La** 138.91	58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** [145]	62 **Sm** 150.36	63 **Eu** 151.96	64 **Gd** 157.25	65 **Tb** 158.93	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.05	71 **Lu** 174.97
89 **Ac** [227]	90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 **Np** [237]	94 **Pu** [244]	95 **Am** [243]	96 **Cm** [247]	97 **Bk** [247]	98 **Cf** [251]	99 **Es** [252]	100 **Fm** [257]	101 **Md** [258]	102 **No** [259]	103 **Lr** [262]

Formula Sheet

Length
1 kilometer = 0.62137 mile
1 inch = 2.54 centimeters (exactly)
1 Ångstrom = 1×10^{-10} meter

Energy
1 joule = 1 $kg \cdot m^2/s^2$
1 calorie = 4.184 joules
1 Calorie = 1 kilocalorie = 1000 calories
1 L·atm = 101.325 joules

Pressure
1 pascal = 1 N/m^3 = 1 $kg/m \cdot s^2$
1 atmosphere = 101.325 kilopascals = 760 mm Hg = 760 torr = 14.70 lb/in^2
1 bar = 1×10^5 Pa (exactly)

Temperature
0 K = −273.15°C
K = °C + 273.15
°C = (5/9)(°F − 32)

Mass
1 kg = 2.205 lbs

Volume
1 mL = 1 cm^3 = 1 cc

Constants
c = 2.998×10^8 m/sec
h = 6.626×10^{-34} J·sec
R = 0.08206 L·atm/mol·K = 8.314 J/mol·K
Specific heat of water = 4.184 J/g·K
Mass of an electron: 9.109×10^{-31} kg
Mass of a proton: 1.673×10^{-27} kg
RH = 2.18×10^{-18} J
Specific heat of water = 4.184 J/g·K
Avogadro's number: 6.022×10^{23}
F = 96485 J/(V·mol e^-)
$K_w = 1.0 \times 10^{-14}$ at 25 °C
$k_b = 1.381 \times 10^{-23}$ J/K

Equations
$(P + a(n^2/V^2))\cdot(V - nb) = nRT$
molar mass (M) = mRT/PV
density (d) = MP/RT

$$KE = \frac{3}{2}RT$$

$$\mu_{rms} = \sqrt{\frac{3RT}{M}}$$

$$\frac{Rate\ of\ effusion\ A}{Rate\ of\ effusion\ B} = \sqrt{\frac{MW_B}{MW_A}}$$

$$\Delta E = -2.18 \times 10^{-18} J \left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

$$\ln\left(\frac{P_2}{P_1}\right) = \frac{\Delta H_{vap}}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

$C_g = kP_g$
$P_{solution} = P_{solvent}\, X_{solvent}$
$P_{solution} = \sum P_j = \sum P_j X_j$
$\pi = MRTi$

Thermodynamic and Electrochemistry

$S = k_b \times \ln(W)$
$\Delta S = q_{rev}/T$
$\Delta G = \Delta G° + RT \cdot \ln Q$
R=8.314 J/mol.K
$\Delta G° = -RT \cdot \ln K$
$\Delta G = -nFE_{cell}$
$E°_{cell} = RT/nF \ln K$
$E°_{cell} = (0.0257/n) \ln K = (0.0592/n) \log K$
$E_{cell} = E°_{cell} - (RT/nF) \ln Q$
$E_{cell} = E°_{cell} - (0.0257/n) \ln Q$
Electrolysis: Q (total charge) = I × t = n × F

Integrated Rate Laws & half-life

$$\ln\frac{[A]}{[A]_0} = -kt$$

$$\frac{1}{[A]} = kt + \frac{1}{[A]_0}$$

$$[A] = -kt + [A]_0$$

$$t_{1/2} = \frac{[A]_0}{2k}$$

$$t_{1/2} = \frac{\ln 2}{k} = \frac{0.693}{k}$$

$$t_{1/2} = \frac{1}{k[A]_0}$$

$$ln\frac{k_2}{k_1} = -\frac{E_a}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

Equilibrium and Acid / Base

$K_P = K_c \times (RT)^{\Delta n}$

$$ln\frac{K_2}{K_1} = \frac{\Delta H^{\circ}_{rxn}}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$