Chem 10113, Exam 1 **Answer Key**

September 25, 2019

1. Write a ***complete, balanced chemical equation*** for each of the following processes.

   (a) (3 points) The combustion of acetone, $(CH_3)_2CO$.

   $(CH_3)_2CO \;+\; 4\,O_2 \;\longrightarrow\; 3\,CO_2 \;+\; 3\,H_2O$

   (b) (3 points) The preparation of barium phosphate by a ***neutralization*** reaction.

   $2\,H_3PO_4 \;+\; 3\,Ba(OH)_2 \;\longrightarrow\; Ba_3(PO_4)_2 \;+\; 6\,H_2O$

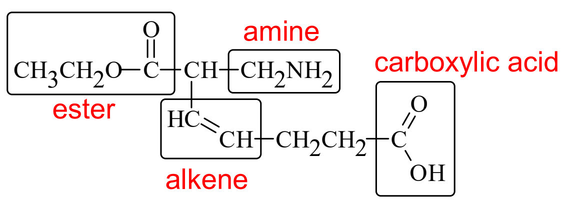
   (c) (3 points) The addition of $HBrO_3$ to water.

   $HBrO_3 \;+\; H_2O \;\longrightarrow\; H_3O^+ \;+\; BrO_3^-$

2. (18 points) Write the chemical formula for each of the following compounds.

Name	**Formula**
lead(IV) oxalate	$Pb(C_2O_4)_2$
aluminum permanganate	$Al(MnO_4)_3$
ammonium tellurite	$(NH_4)_2TeO_3$
hydrosulfuric acid	$H_2S_{(aq)}$
copper(II) thiosulfate tetrahydrate	$CuS_2O_3 \cdot 4H_2O$
nickel(III) cyanate	$Ni(OCN)_3$
bromic acid	$HBrO_{3(aq)}$
calcium peroxide	CaO_2
diantimony pentasulfide	Sb_2S_5

3. (4 points) In the following organic compound, identify the functional groups by writing the appropriate family name (i.e., alcohol, ether, ketone, etc.) next to each box.



4. (8 points) **SHOW ALL WORK.** A certain hydrate has the formula $Fe(NO_3)_3 \cdot xH_2O$. The water in a 2.787 g sample of the hydrate was driven off by heating. The remaining sample had a mass of 1.668 g. Determine the number of waters of hydration (x) in the hydrate. {molar masses: H_2O = 18.0, $Fe(NO_3)_3$ = 241.2}

   2.787 g - 1.668 g = 1.119 g H_2O

   (1.119 g H_2O) (1 mole / 18.0 g) = 0.06216 mole H_2O

   (1.668 g $Fe(NO_3)_3$) (1 mole / 241.2 g) = 0.006915 mole $F3(NO_3)_3$

   x = moles H_2O / moles $Fe(NO_3)_3$ = 0.06216 / 0.006915 = 8.99 ~ **9**

5. Boron carbide, **B_4C (specific gravity = 2.52)**, is a high-tech, super-hard ceramic material that is used in armor plating and similar applications. (***Note***: *The following four questions are all related to B_4C but they can be answered independently of each other!*)

(a) (7 points) **SHOW ALL WORK.** Determine the number of boron atoms in 5.00 *femto*grams of B_4C (molar mass = 55.25).

$(5.00 \times 10^{-15}$ g)(1 mole B_4C / 55.25 g)(4 mole B / mole B_4C)(6.022×10^{23} atoms / mole)

= 2.18×10^{8} B atoms

(b) (3 points) Boron carbide is prepared commercially by the high-temperature reaction of boron oxide and graphite as follows. Balance this chemical equation.

$$2\,B_2O_3 + 7\,C \longrightarrow 6\,CO + B_4C$$

(c) (10 points) **SHOW ALL WORK.** Boron carbide can be deposited on surfaces as extremely thin films. Imagine that 3.00 mg of B_4C covers a 5.00 x 7.00 inch index card in a thin, even layer. Determine the thickness of the layer in *nano*meters.

volume = $(3.00 \times 10^{-3}$ g) (1 cm^3 / 2.52 g) = 1.191×10^{-3} cm^3

area = (35.0 in^2) $(2.54\ cm/in)^2$ = 225.8 cm^2

thickness = (1.191×10^{-3} cm^3) / (225.8 cm^2) = 5.272×10^{-6} cm

(5.272×10^{-6} cm) (10^{-2} m / cm) (1 nm / 10^{-9} m) = 52.7 nm

(d) (10 points) **SHOW ALL WORK.** In the laboratory, B_4C can be prepared by the reaction of a boron hydride such as decaborane, $B_{10}H_{14}$, with acetylene, C_2H_2, as shown in the following balanced equation. In one such experiment, when 100.0 g of $B_{10}H_{14}$ and 30.0 g of C_2H_2 were allowed to react, the chemist obtained 106 g of pure B_4C. Determine the percentage yield of the reaction. (molar masses: $B_{10}H_{14}$ = 122.2, C_2H_2 = 26.04, B_4C = 55.25)

$$4\,B_{10}H_{14} + 5\,C_2H_2 \longrightarrow 10\,B_4C + 33\,H_2$$

Starting quantities:

(100.0 g $B_{10}H_{14}$) (1 mole / 122.2 g) = 0.8183 mole $B_{10}H_{14}$

(30.0 g C_2H_2) (1 mole / 26.04 g) = 1.152 mole C_2H_2

Limiting Reactant?

(0.8183 mole $B_{10}H_{14}$) (10 mole B_4C / 4 mole $B_{10}H_{14}$) = 2.046 mole B_4C

(1.152 mole C_2H_2) (10 mole B_4C / 5 mole C_2H_2) = 2.304 mole B_4C

$\therefore$ $B_{10}H_{14}$ is the Limiting Reactant and

the Theoretical Yield of B_4C = 2.046 mole (55.26 g/mole) = 113.1 g

Percent Yield of B_4C = (106 g) / (113.1 g) x 100 % = 93.7 %

6. (9 points) **SHOW ALL WORK.** A mixture of carbon and sulfur has a total mass of 5.0 g. Complete combustion with an excess of O_2 gives 13 g of a mixture of CO_2 and SO_2. Determine the mass of carbon in the original mixture. (***Hint***: ***Think <u>moles</u>*** as well as grams. For simplicity, round any atomic masses that you use to just two significant figures.)

Let x = moles C = moles CO_2 and y = moles S = moles SO_2

Now write two equations based on given masses of the mixtures, in terms of x and y.

mass C + mass S = 5.0 g = (12 g/mole)(x mole) + 32 g/mole)(y mole)

mass CO_2 + mass SO_2 = 13 g = (44 g/mole)(x mole) + (64 g/mole)(y mole)

or simply, eq 1: 5 = 12x + 32y and eq 2: 13 = 44x + 64y

solve eq 1 for y = (5 - 12x)/32 and substitute into eq 2:

13 = 44x + 64(5 - 12x)/32 = 44x + 10 - 24x = 20x + 10

solve for x = (13 - 10)/20 = 3/20 = 0.15 mole C

mass C = (0.15 mole C) (12 g/mole) = 1.8 g C

7. (8 points) **SHOW ALL WORK.** An aqueous solution of nitric acid is 50.0 % HNO_3 by mass. The density of this solution is 1.310 g/mL. Determine the molarity of the solution.
(molar masses: H_2O = 18.02, HNO_3 = 63.02)

50.0 % HNO_3 means that 100 g solution contains 50.0 g HNO_3

(50.0 g HNO_3) (1 mole / 63.02 g) = 0.7934 mole HNO_3

volume of the 100 g solution = (100 g) (1 mL / 1.310 g) = 76.33 mL = 0.07633 L

molarity = moles solute / L of solution = (0.7934 mole HNO_3 / 0.07633 L

= 10.4 M

8. Many metals react with acids to produce hydrogen gas as illustrated by the following reaction. (molar masses: Al = 26.98, H_2SO_4 = 98.09, H_2 = 2.02)

$$2\,Al_{(s)} + 3\,H_2SO_{4(aq)} \longrightarrow Al_2(SO_4)_{3(aq)} + 3\,H_{2(g)}$$

(a) (9 points) **SHOW ALL WORK.** Determine the mass of Al (in grams) that is required to react exactly with 300.0 mL of 1.50 M H_2SO_4 solution.

(300.0 mL) (1.50 mole H_2SO_4 / 1000 mL) = 0.450 mole H_2SO_4

(0.450 mole H_2SO_4) (2 mole Al / 3 mole H_2SO_4) = 0.300 mole Al

(0.300 mole Al) (26.98 g / mole) = 8.09 g

(b) (5 points) **SHOW ALL WORK.** Determine the volume (in mL) of 15.0 M H_2SO_4 that is required to prepare the 300.0 mL of 1.50 M H_2SO_4 used in part (a).
Note: The answer to part (a) is not required here!

moles H_2SO_4 = V_dM_d = V_cM_c

(300 mL) (1.50 mole/1000 mL) = V_c (15.0 mole/1000 mL)

V_c = 30.0 mL