Dr. Zellmer | Chemistry 1250 | T, R
Time: 7 PM Sun. | Spring Semester 2022 | February 6, 2022
40 min | Quiz III

Name KEY Lab TA/time

1. (3 pts) Cisplatin, an anticancer drug, has the molecular formula $Pt(NH_3)_2Cl_2$. How many **moles** of hydrogen **atoms** are in 2.8 x 10^{-4} g of cisplatin?
(At. Wts.: H = 1.008, N = 14.01, Cl = 35.45, Pt = 195.1 ; Mol. wt: 300.07)

$$1 \text{ mol } Pt(NH_3)_2Cl_2 = 6.02 \times 10^{23} \text{ } Pt(NH_3)_2Cl_2 \text{ molecules} = 300.07 \text{ g } Pt(NH_3)_2Cl_2$$

$$\text{Also, } 1 \text{ mol } Pt(NH_3)_2Cl_2 = 6 \text{ mol H atoms}$$

$$? \text{ mol H atoms} = 2.8 \times 10^{-4} \text{ g } Pt(NH_3)_2Cl_2 \times \frac{1 \text{ mol } Pt(NH_3)_2Cl_2}{300.07 \text{ g } Pt(NH_3)_2Cl_2} \times \frac{6 \text{ mol H atoms}}{1 \text{ mol } Pt(NH_3)_2Cl_2}$$

$$= 5.5986 \times 10^{-6} \text{ moles H atoms}$$

$$= 5.6 \times 10^{-6} \text{ moles H atoms}$$

2. (3 pts) Sodium carbonate has the formula, Na_2CO_3. How **many sodium ions** are present in 0.10 g of Na_2CO_3? (At. Wts.: C = 12.01, O = 16.00, Na = 22.99; Form. Wt.: Na_2CO_3 = 105.99)

$$1 \text{ mole } Na_2CO_3 = 6.02 \times 10^{23} \text{ } Na_2CO_3 \text{ f.u.} = 105.99\text{g } Na_2CO_3$$

$$\text{Also, } 1 \text{ mole of } Na_2CO_3 \text{ f.u.} = 2 \text{ mol } Na^+ \text{ ions } \& \ 1 \text{ } Na_2CO_3 \text{ f.u.} = 2 \text{ } Na^+ \text{ ions}$$

$$? \text{ } Na^+ \text{ ions} = 0.10 \text{ g } Na_2CO_3 \times \frac{1 \text{ mol } Na_2CO_3}{105.99 \text{ g } Na_2CO_3} \times \frac{6.02 \times 10^{23} \text{ } Na_2CO_3 \text{ f.u.}}{1 \text{ mol } Na_2CO_3} \times \frac{2 \text{ } Na^+ \text{ ions}}{1 \text{ mol } Na_2CO_3}$$

$$= 1.135 \times 10^{21} \text{ } Na^+ \text{ ions}$$

$$= 1.1 \times 10^{21} \text{ } Na^+ \text{ ions}$$

or

$$? \text{ } Na^+ \text{ ions} = 0.10 \text{ g } Na_2CO_3 \times \frac{1 \text{ mol } Na_2CO_3}{105.99 \text{ g } Na_2CO_3} \times \frac{2 \text{ mol } Na^+ \text{ ions}}{1 \text{ mol } Na_2CO_3} \times \frac{6.02 \times 10^{23} \text{ } Na^+ \text{ ions}}{1 \text{ mol } Na^+ \text{ ions}}$$

$$= 1.1 \times 10^{21} \text{ } Na^+ \text{ ions}$$

3. (7 pts) An analysis of a compound containing only carbon and fluorine gives a mass percent composition of 21.32% C and 78.68% F. The experimentally determined molecular weight is 507 amu. (At. Wt.: C = 12.011, F = 18.998)

Must determine empirical formula first

Assume a 100 g sample

21.32 g C   78.68 g F

Step 1: convert to moles

C: $21.32 \text{ g C} \times \dfrac{1 \text{ mole C}}{12.011 \text{ g C}} = 1.7750 \text{ mol C}$ (4 s.f.)

F: $78.68 \text{ g F} \times \dfrac{1 \text{ mole F}}{18.998 \text{ g F}} = 4.1414 \text{ mol F}$ (4 s.f.)

Step 2: find mole ratio (divide each by smallest # moles)- this is also atom ratio in empirical formula.

C: $\dfrac{1.7750}{1.7750} = 1.000$ F: $\dfrac{4.1414 \text{ mol F}}{1.7750 \text{ mol C}} = 2.333$

$C_1 F_{2.333}$ can't have fractional subscripts, so multiply subscripts by 3 (if you try multiplying by 2 you are not close enough to a whole number - you get 4.666 F atoms)

EF is C_3F_7

EFW = 169.02 amu (empirical formula weight)

b) (2 pts) What is the **molecular formula**? Not asked for on the quiz.

Step 3: determine the molecular formula. The MF is always an integer multiple of the empirical formula, EF. Thus the MW is the same multiple of the EFW.

$$MW = n \times EFW$$

$$n = \frac{MW}{EFW} = \frac{507 \text{ amu}}{169.02 \text{ amu}} = 2.99 = 3$$

$$MF = (EF)_n = (C_3F_7)_3 = \boxed{C_9F_{21}}$$

4. (7 pts) A 0.589 g sample of an organic compound containing only carbon, hydrogen and oxygen was burned completely in air to produce 0.733 g of CO_2 and 0.299 g of H_2O. What is the empirical formula of the compound? (Atomic weights: C = 12.01, H = 1.008, O = 16.00)

This is an empirical formula problem using combustion analysis. In CA the sample undergoes complete combustion. All the Carbon winds up in the CO_2 and the Hydrogen winds up in the H_2O . If there is one other atom its mass can be determined by remembering the conservation of mass, in this case oxygen.

In this problem a 0.589 g sample produces 0.733 g of CO_2 and 0.299 g H_2O.

Can do this in a couple of ways. In lecture I converted the masses of CO_2 and H_2O into the masses of C and H atoms present in the original sample by using mass fractions. Then I got the mass of the third atom (in this case oxygen) by using the Law of Conservation of mass. Then I converted all the masses to moles.

Here I'm converting the masses of CO_2 and H_2O into the moles of C and H atoms present in the original sample since we need that anyway and then converting that to the masses of C and H atoms present in the original sample. Then those are used to obtain the mass of oxygen which is then converted to moles of oxygen.

Determine moles and mass of C and H in the sample:

$$? \text{ mol C} = 0.733 \text{ g } CO_2 \times \frac{1 \text{ mol } CO_2}{44.01 \text{ g } CO_2} \times \frac{1 \text{ mol C}}{1 \text{ mol } CO_2} = 0.016\underline{\mathbf{6}}5 \text{ mol C (3 s.f.)}$$

$$? \text{ mol H} = 0.299 \text{ g } H_2O \times \frac{1 \text{ mol } H_2O}{18.016 \text{ g } H_2O} \times \frac{2 \text{ mol H}}{1 \text{ mol } H_2O} = 0.033\underline{\mathbf{1}}9 \text{ mol H (3 s.f.)}$$

Need moles of oxygen but have to get mass first. Need to calculate mass of C and H and subtract from the total mass of sample to get the mass of oxygen.

$$? \text{ g C} = 0.016\underline{\mathbf{6}}5 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} = 0.20\underline{\mathbf{0}}0 \text{ g C (3 s.f.)}$$

$$? \text{ g H} = 0.033\underline{\mathbf{1}}9 \text{ mol H} \times \frac{1.008 \text{ g H}}{1 \text{ mol H}} = 0.033\underline{\mathbf{4}}5 \text{ g H (3 s.f.)}$$

$$? \text{ g O} = 0.589 \text{ g sample} - (0.20\underline{\mathbf{0}}0 \text{ g C} + 0.033\underline{\mathbf{4}}5 \text{ g H}) = 0.35\underline{\mathbf{5}}5 \text{ g O}$$

Find moles of O:

$$? \text{ mol O} = 0.35\underline{\mathbf{5}}5 \text{ g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 0.022\underline{\mathbf{2}}1 \text{ mol O (3 s.f.)}$$

***** continued on next page *****

4. (Cont.)

Empirical Formula calculations:

Divide each of the moles by the smallest number of moles (in this case O).

$$C: \frac{0.01665 \text{ mol C}}{0.01665 \text{ mol C}} = 1.00 \times 3 = 3.00 = 3$$

$$H: \frac{0.03345 \text{ mol H}}{0.01665 \text{ mol C}} = 1.99 \times 3 = 5.97 = 6$$

$$O: \frac{0.02221 \text{ mol O}}{0.01665 \text{ mol C}} = 1.33 \times 3 = 3.99 = 4$$

Can't have non-integer ratios (subscripts). Have to multiply by a factor to get integers. Must multiply each one by 3 (multiplying by 2 won't give a number close enough to an integer for oxygen).

$C_3H_6O_4$

5. (4 pts) Given the balanced equation below, how many moles of hydrogen can be produced from the complete reaction of 3.860×10^{-1} mol of Fe with excess water? (At. Wts.: H = 1.008, O = 16.00, Fe = 55.85)

$$3\,Fe(s) + 4\,H_2O(g) \rightarrow Fe_3O_4(aq) + 4\,H_2(g)$$

mole-to-mole stoichiometry problem

$$?\text{ mol } H_2 = 0.386\underline{\mathbf{0}} \text{ mol Fe} \times \frac{4 \text{ mol } H_2}{3 \text{ mol Fe}} = 0.514666 = 0.5147 \text{ mole } H_2.$$

6. (5 pts) How many **grams** of oxygen (O_2), reacting with excess C_2H_6, are required to form 35.0 g of carbon dioxide (CO_2), according to the following equation? (At. Wt.: H = 1.01 O = 16.00, C = 12.01; Mol. Wt: C_2H_6 = 30.08, O_2 = 32.00, CO_2 = 44.01, H_2O = 18.02)

$$2\,C_2H_6 + 7\,O_2 \rightarrow 4\,CO_2 + 6\,H_2O$$

gram → gram stoich

$$?\text{ g } O_2 = 35.0 \text{ g } CO_2 \times \frac{1 \text{ mol } CO_2}{44.01 \text{ g } CO_2} \times \frac{7 \text{ mol } O_2}{4 \text{ mol } CO_2} \times \frac{32.00 \text{ g } O_2}{1 \text{ mol } O_2} = 44.\underline{\mathbf{5}}35 \text{ g } O_2 = 44.5 \text{ g } O_2 \text{ (3 s.f.)}$$

$$\text{grams desired} = \text{grams given} \times \frac{\text{moles given}}{\text{grams given}} \times \frac{\text{moles desired}}{\text{moles given}} \times \frac{\text{grams desired}}{\text{moles desired}}$$

grams given ⇒ mol given ⇒ mol desired ⇒ grams desired

7. (6 pts) Calcium hydroxide reacts with phosphoric acid according to the following equation. Which substance is the limiting reagent when 1.00 mol of $Ca(OH)_2$ reacts with 0.50 mol of H_3PO_4? How many moles of the excess reagent remain after completion of the reaction?

$$3\ Ca(OH)_2\ (s)\ +\ 2\ H_3PO_4\ (aq)\ \rightarrow\ Ca_3(PO_4)_2\ (aq)\ +\ 6\ H_2O\ (\ell)$$

This is a limiting reactant problem. These are just stoichiometry problems. There is more than one way to do a LR problem. In this case since it's asking for the limiting reactant and the mass of excess reactant remaining after completion of the reaction.

1) Method 1: Calculate which reactant gives the smallest number of moles of product, and then use to determine how much of the excess reactant would be used (and remains).

Calculate mol $Ca_3(PO_4)_2$ from $Ca(OH)_2$ and H_3PO_4 :

$$?\ \text{mol } Ca_3(PO_4)_2 = 1.00\ \text{mol } Ca(OH)_2 \times \frac{1\ \text{mol } Ca_3(PO_4)_2}{3\ \text{mol } Ca(OH)_2} = 0.33\underline{3}3\ \text{mol } Ca_3(PO_4)_2\ \text{(3 s.f.)}$$

$$?\ \text{mol } Ca_3(PO_4)_2 = 0.50\ \text{mol } H_3PO_4 \times \frac{1\ \text{mol } Ca_3(PO_4)_2}{2\ \text{mol } H_3PO_4} = 0.2\underline{5}00\ \text{mol } Ca_3(PO_4)_2\ \text{(3 s.f.)}\ \textbf{LR}$$

Fewer moles of $Ca_3(PO_4)_2$ obtained from the H_3PO_4 so the **H_3PO_4** is the **LR** and only $0.2\underline{5}00$ moles of $Ca_3(PO_4)_2$ are formed. Calculate the moles of $Ca(OH)_2$ required to produce $0.2\underline{5}00$ mol of $Ca_3(PO_4)_2$

$$?\ \underset{\text{used}}{\text{mol } Ca(OH)_2} = 0.2\underline{5}00\ \text{mol } Ca_3(PO_4)_2 \times \frac{3\ \text{mol } Ca(OH)_2}{1\ \text{mol } Ca_3(PO_4)_2} = 0.7\underline{5}0\ \text{mol } Ca(OH)_2\ \textbf{used}\ \text{(2 s.f.)}$$

$$?\ \text{mol } Ca(OH)_2 = 1.00\ \text{mol } Ca(OH)_2 - 0.7\underline{5}0\ \text{mol } Ca(OH)_2 = 0.2\underline{5}0\ \text{mol } Ca(OH)_2\ \text{remaining}$$

H_3PO_4 is LR **0.25 mol $Ca(OH)_2$ remaining**

2) Method 2: Determine mole ratio of the two reactants & compare it to the mole ratio in the bal. eqn.

$$\frac{1.00\ \text{mol } Ca(OH)_2}{0.50\ \text{mol } H_3PO_4} > \frac{3\ \text{mol } Ca(OH)_2}{2\ \text{mol } H_3PO_4}$$

Since the actual ratio of $Ca(OH)_2$ to H_3PO_4 (ratio = 2) is greater than that from the bal. eqn. (ratio = 1.5) this means $Ca(OH)_2$ is in excess and H_3PO_4 is the LR. Can then calculate the moles of $Ca(OH)_2$ required to react with the H_3PO_4.

$$?\ \text{mol } Ca(OH)_2 = 0.50\ \text{mol } H_3PO_4 \times \frac{3\ \text{mol } Ca(OH)_2}{2\ \text{mol } H_3PO_4} = 0.7\underline{5}0\ \text{mol } Ca(OH)_2\ \text{used (3 s.f.)}$$

8. (3 pts) Which of the following are **strong electrolytes**?

HF **HCl** **$Cu(ClO_3)_2$** **$Ca(OH)_2$** C_2H_5OH

All soluble ionic substances (salts) are strong electrolytes. All strong acids and bases are strong electrolytes. You need to memorize these. All other molecular substances that dissolve are either weak or non-electrolytes.

The 7 strong acids are: HCl, HBr, HI binary acids

HNO_3, $HClO_3$, $HClO_4$, H_2SO_4 (1^{st} H^+ only) oxyacids (ternary)

Strong bases are group 1 A and 2 A hydroxides are the most common. We will learn others in Ch 16.

The following are strong electrolytes:

HCl strong acid

$Cu(ClO_3)_2$ soluble ionic cmpd.

$Ca(OH)_2$ strong base (ionic as well)

The following are weak electrolytes:

HF weak acid

C_2H_5OH molecular (nonelectrolyte)

9. (4 pts) **Predict the products** of the following reaction. **Complete and balance** the equation. **Indicate the physical state** of reactants and products (i.e. (s), (g), (l), (aq)). **(Show all work.)**

A solution of nitric acid, HNO_3, is combined with a solution of $Ca(OH)_2$.

Neutralization Rxn: Treat as an exchange rxn. - switch partners

$$\underset{\text{acid}}{HNO_3\,(aq)} + \underset{\text{hydroxide base}}{Ca(OH)_2\,(aq)} \rightarrow \underset{\text{ionic (salt)}}{Ca^{2+}\,(NO_3)^{1-}\,(aq)} + \underset{\text{water}}{H^+\,OH^-\,(\ell)}$$

charges on ions do not change when they switch partners in double replacement rxns

$$HNO_3\,(aq) + Ca(OH)_2\,(aq) \rightarrow Ca(NO_3)_2\,(aq) + H_2O\,(\ell)$$

Bal: (start w. NO_3^- - there's two of them on the right and it's on the left like a poly atomic ion. You generally want to balance polyatomic ions as a unit after balancing other things, but before H and O)

$$\underset{\substack{\text{acid}\\ \text{(soluble)}}}{2\,HNO_3\,(aq)} + \underset{\substack{\text{hydroxide base}\\ \text{(soluble)}}}{Ca(OH)_2\,(aq)} \rightarrow \underset{\substack{\text{ionic (salt)}\\ \text{(soluble)}}}{Ca(NO_3)_2\,(aq)} + \underset{\text{water}}{2\,H_2O\,(\ell)}$$

Look in solubility table to see if substances are soluble (aq) or a precipitate (solid) or determine if one of the products breaks down to give a gas (CO_2, SO_2 or H_2S).

10. (3 pts) What are the expected products of the following reaction?

$CaSO_3$ (s) + 2 HNO_3 (aq) $\longrightarrow$

$CaSO_3$ (s) + 2 HNO_3 (aq) → $Ca(NO_3)_2$ (s) + H_2SO_3 (aq)

Sulfurous acid is unstable and decomposes

H_2SO_3 (aq) → H_2O (ℓ) + SO_2 (g)

Overall final equation:

$CaSO_3$ (s) + 2 HNO_3 (aq) → $Ca(NO_3)_2$ (s) + H_2O (ℓ) + SO_2 (g)

Exchange (double-replacement) with the formation of a **gas**.

Carbonates (CO_3^{2-}) and bicarbonates (HCO_3^{-}) react with acids to give **CO_2** (g).

Sulfites (SO_3^{2-}) and bisulfites (HSO_3^{-}) react with acids to give **SO_2** (g).

Sulfides (S^{2-}) react with acids to give **H_2S** (g).

11. (4 pts) Determine the oxidation number of the underlined element in the following compound. (**Must show all work.**)

Chg. on $\underline{\mathbf{Cr}}_2O_7^{2-}$ is -2

a) (2 pts) $\underline{\mathbf{Cr}}_2O_7^{2-}$ $2X_{Cr} + 7(-2)_O = -2$; $2X_{Cr} - 14 = -2$; $2X_{Cr} = +12$; $X_{Cr} = +6$

The ox. no. on chromium is **+6**.

Chg. on P_4O_6 is 0

b) (2 pts) $\underline{\mathbf{P}}_4O_6$ $4X_P + 6(-2)_O = 0$; $4X_P - 12 = 0$; $4X_P = +12$; $X_P = +3$

The ox. no. on phosphorous is **+3**.

12. (5 pts) Which of the following is (are) an example(s) of a **redox** reaction (assume all reactions occur to give products)?

1) $Pb(NO_3)_2$ (aq) + NaBr (aq) → exchange reaction

2) $CaSO_4$ (aq) + $(NH_4)_3PO_4$ (aq) → exchange reaction

3) NaI (aq) + Br_2 (ℓ) → redox

4) Fe (s) + HCl (aq) → redox

5) Ba (s) + O_2 (g) → redox

a) 3, 5 b) 1, 2 c) 4, 5 d) 2, 3, 4 e)* 3, 4, 5

Oxidation-Reduction (Redox) reactions involve the transfer of electrons (and associated change in oxidation numbers)..

Remember (OIL RIG):

oxidation: loss of e-, inc. in oxidation #

reduction: gain of e-, dec. in oxidation #

See above answers in #8. **Displacement** (single-replacement) and **combination** rxns are some examples of redox rxns.

3) NaI (aq)	+	Br_2 (ℓ)	→	NaBr (aq)	+ I_2 (s)	single replacement
-1		0		-1	0	
ionic halide		element halogen		ionic halide	element halogen	

I oxidized (NaI reducing agent) Br reduced (Br_2 oxidizing agent)

4) Fe (s)	+	2 HCl (aq)	→	$FeCl_2$ (aq)	+ H_2 (g)	single replacement
0		+1		+2	0	
element		acid (Acts like ionic in solution)		ionic	element	

Fe oxidized (Fe reducing agent) H reduced (HCl oxidizing agent)

5) 2 Ba (s)	+	O_2 (g)	→	2 BaO(s)	combination
0		0		+2 -2	
element		element		ionic cmpd	(2 reactants → 1 product)

Ba oxidized (reducing agent) O reduced (O_2 oxidizing agent)

(3, 4, 5)