CHEMISTRY 101
Hour Exam II
March 26, 2024
Dr. E. McCarren

Name ________________KEY___________

Signature ___________________________

Section _____________________________

"You must believe in spring." – Bill Evans

This exam contains 17 questions on 8 numbered pages. Check now to make sure you have a complete exam. You have one hour and thirty minutes to complete the exam. Determine the best answer to the first 15 questions and enter these on the special answer sheet. Also, circle your responses in this exam booklet. Show all of your work and provide complete answers to questions 16 and 17.

1-15	(30 pts.)	_________
16	(12 pts.)	_________
17	(18 pts.)	_________
Total	(60 pts)	_________

Useful Information:
1 L = 1000 mL (exactly)

Always assume ideal behavior for gases (unless explicitly told otherwise).

$PV = nRT$ $\quad$ $R = 0.08206$ L·atm/mol·K

$K = °C + 273$ $\quad$ $N_A = 6.022 \times 10^{23} = 1$ mole

Standard temperature and pressure (STP) is 1.0 atm and 273 K.

Solubility Rules:

1. Most nitrate salts are soluble.
2. Most salts of sodium, potassium, and ammonium cations are soluble.
3. Most chloride salts are soluble. Exceptions: silver(I), lead(II), and mercury(I) chloride.
4. Most sulfate salts are soluble. Exceptions: calcium, barium, and lead(II) sulfate.
5. Most hydroxide salts can be considered insoluble. Soluble ones: sodium, potassium, ammonium, and calcium hydroxide.
6. Consider sulfide, carbonate, and phosphate salts to be insoluble. Soluble ones: sodium, potassium, and ammonium.

Section 1: Multiple Choice

1. Balance the follow chemical equation in standard form and determine the sum of the coefficients.

$$\mathbf{Mg(s) + \quad Mn_2O_3(s) \rightarrow \quad MgO(s) + \quad Mn(s)}$$

   a. 4
   b. 6
   c. 7
   d. 8
   e. **9**

2. The arrow symbol (→) separates the left and right sides of a balanced chemical equation. Consider the portion of a chemical equation to the left side of the arrow. Which is **true** about the left side of a balanced equation?

   The left side of a balanced equation shows….
   a. the number of moles of each substance which are present in the reaction container before a reaction happens.
   b. **the identities of the substances which are required for a reaction to occur.**
   c. which substances can be formed as a result of a reaction.
   d. Two of the above (a-c) are true.
   e. All of the above (a-c) are true.

Consider the reaction for the elephant's toothpaste demonstration, which involves the decomposition of hydrogen peroxide to form liquid water and gaseous oxygen shown by the balanced equation below. Use this equation to answer the next two questions.

$$\mathbf{2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)}$$

3. If 4.50 moles of hydrogen peroxide decompose, how many moles of oxygen gas will be formed?
   a. 1.13 moles
   b. **2.25 moles**
   c. 4.50 moles
   d. 6.75 moles
   e. 9.00 moles

4. In a separate reaction, some hydrogen peroxide decomposes and 60.0 grams of water forms. How many moles of oxygen gas were also produced in this process?
   a. 53.3 moles
   b. 30.0 moles
   c. 6.66 moles
   d. 3.33 moles
   e. **1.66 moles**

Nitrogen gas and hydrogen gas react to form ammonia gas according to the balanced equation below. Use this equation to answer the next two questions.

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

5. Consider a scenario in which 20.0 L of hydrogen gas at 25.0°C and 1.0 atm of pressure react with sufficient nitrogen gas to form ammonia. How many moles of ammonia can be produced from this quantity of hydrogen gas?
   a. **0.545 mol**
   b. 0.818 mol
   c. 0.975 mol
   d. 1.22 mol
   e. 6.50 mol

6. In a separate scenario, some nitrogen and some hydrogen react. **After** this reaction, 12 moles ammonia were formed and 4.0 moles of nitrogen gas were leftover. How many moles of **nitrogen gas** were present **before** the reaction?
   a. 4.0 moles
   b. 6.0 moles
   c. **10. moles**
   d. 12 moles
   e. 18 moles

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7. Recall the lab activity when you observed the combinations of several aqueous solutions, similar to those combinations shown in the table below. For how many of the combinations below are precipitates expected to form?

	silver nitrate	**barium nitrate**
sodium sulfate	**no**	**ppt**
potassium carbonate	**npt**	**ppt**

   a. 0 (None of the combinations will form precipitates.)
   b. 1
   c. 2
   d. **3**
   e. 4 (All four combinations will form precipitates.)

8. For the combination of potassium carbonate and barium nitrate, what is the formula of the precipitate?
   a. KNO_3
   b. K_2NO_3
   c. Ba_2CO_3
   d. **$BaCO_3$**
   e. No precipitate was formed in this combination.

In the lab, we saw reactions between two acids and baking soda, which is basic. One of the reactions is shown below. Finish filling in the table below, determining the moles of carbon dioxide produced for trials 1 and 2. Use this information to answer the next three questions.

Reaction 1: **$2NaHCO_3(s) + H_2SO_4(aq) \rightarrow 2CO_2(g) + 2H_2O(l) + Na_2SO_4(aq)$**

(aq)

	Moles $NaHCO_3$	Moles H_2SO_4	Moles CO_2 produced	Limiting reactant
Trial #1	0.200	0.200		
Trial #2	0.200	0.100		

9. How many moles of carbon dioxide are expected to be produced in trial #1?
   a. 0.100 mol
   b. **0.200 mol**
   c. 0.300 mol
   d. 0.400 mol
   e. 0.500 mol

10. What quantity of excess reactant is left over after the reaction in trial #1 occurs? Select the correct quantity and identity.
   a. **0.100 mol H_2SO_4**
   b. 0.050 mol H_2SO_4
   c. 0.100 mol $NaHCO_3$
   d. 0.050 mol $NaHCO_3$
   e. There was a complete reaction, so there was no limiting reactant.

11. In the lab, we saw that the acid and baking soda reacted to inflate a balloon. How does the size of the balloon inflated in trial #1 compare to the size of the balloon inflated in trial #2? Assume that the size of the balloon corresponds to the amount of carbon dioxide produced.

   The size of the balloon inflated in trial #1 is _______________ the size of the balloon inflated in trial #2.
   a. one-quarter
   b. half
   c. **equal to**
   d. double
   e. four times greater than

Consider the reaction between aqueous sulfuric acid and aqueous sodium hydroxide. The balanced molecular equation for this reaction is shown below. Use this reaction to answer the next four questions.

$$\mathbf{H_2SO_4(aq) + 2NaOH \rightarrow Na_2SO_4(aq) + 2H_2O(l)}$$

12. What is the balanced <u>net ionic</u> equation for this reaction?
    a. $SO_4^{2-}(aq) + 2Na^+(aq) \rightarrow Na_2SO_4(aq)$
    b. $SO_4^{2-}(aq) + Na_2^+(aq) \rightarrow Na_2SO_4(aq)$
    c. $H_2^+(aq) + 2OH^-(aq) \rightarrow 2H_2O(l)$
    d. **$\underline{H^+(aq) + OH^-(aq) \rightarrow H_2O(l)}$**
    e. It is not possible to write a balanced net ionic equation for this reaction.

You completely neutralize a 200.0 mL solution of 2.50 M H_2SO_4 by adding 300.0 mL NaOH.

13. What was the initial concentration of the NaOH solution before it was added to the sulfuric acid?
    a. <u>3.33 M</u>
    b. 1.88 M
    c. 1.67 M
    d. 1.50 M
    e. 1.00 M

14. After the reaction, is the sulfate ion is still present in the solution? Select yes or no and then the best corresponding explanation.
    a. *Yes,* it formed part of the precipitate.
    b. ***<u>Yes</u>*****<u>, it was a spectator and did not react at all.</u>**
    c. *Yes,* was only partially used in forming the product.
    d. *No,* it was completely used in forming the product.
    e. *No,* it was negatively charged.

15. What was the **concentration** of the sulfate ion in the solution after the reaction?
    a. 0 M
    b. 0.500 M
    c. **<u>1.00 M</u>**
    d. 1.67 M
    e. 2.50 M

Please go on to the next page.

Section 2: Free Response

16. Answer the follow three questions below related to aqueous solutions.

+4 points total

a. You have a 2.00 M solution of calcium chloride ($CaCl_2$) with a volume of 250.0 mL. Consider this to be solution A. How many moles of calcium chloride solute are present in solution A? Show work.

+2 correct equation

+2 numerical answer

$$2.00\ M = \frac{x\ mol\ CaCl_2}{.250\ L} \qquad x = \mathbf{0.500\ mol\ CaCl_2}$$

+4 points total

b. You pour out 50.0 mL of the original 2.00 M solution into a new container and are now left with only 200.0 mL remaining. Consider this remaining 200. mL of solution to be solution B. How many moles of calcium chloride solute are present in solution B? Show work.

+1 using 2.0 M concentration

Solution B also has a concentration of 2.00 M because it came from the original solution A.

+1 correct equation

+2 numerical answer

$$2.00\ M = \frac{x\ mol\ CaCl_2}{.200\ L} \qquad x = \mathbf{0.400\ mol\ CaCl_2}$$

+4 points total

c. Consider a scenario in which you have two solutions, both of which have equal concentrations of 2.0 M. Though the solutions have equal concentrations, they have different volumes. How is this possible? Explain your answer in words and provide a numerical example to support your answer.

+2 coherent explanation

+2 accurate numerical answer

Because concentration is a ratio (moles of solute over total volume of the solution) it is possible that two solutions have the same moles/volume ratio but have different numbers of moles and solution volume. For example, in parts A and B, we see that both solutions have concentrations of 2.00 M, but different moles and volumes. Solution A has 0.500 moles solute and a volume of 0.250 L, which is the same moles/volume ratio as solution B, with 0.400 moles of solute and 0.200 L.

Please go on to the next page.

17. For each of the two scenarios shown below, write the balanced equation for the scenario, including phases. Then, provide explanations and calculations as directed to support your answers to each of the questions.

+3 points total

Scenario 1: Hydrogen gas and oxygen gas react to form liquid water.

+1 reactants

a. Give the balanced equation for this reaction, including phases.

+1 products

$2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$

+1 balance and phases

In a sealed container, 20.0 grams of hydrogen gas reacts with some mass of oxygen gas to form 40.0 grams of water. In this case, the oxygen gas *has* to be the limiting reactant.

+3 points total

b. Explain in words how you know oxygen has to be limiting. In your explanation, be sure to compare the 20.0 g of hydrogen you have to the amount of hydrogen needed to form 40.0 grams of water. Support your answer with calculations.

+2 points for fully coherent explanation

This one can be solved in one of two ways. It is possible to show that either (1) 20.0 grams of hydrogen gas can produce more than 40.0 g of water, or that (2) fewer than 20.0 grams of hydrogen gas are required to produce 40.0 water. See calculations for both options below:

+1 mathematical support**

$$(1)\ \ 20.0\ gH_2 \times \frac{1\ mol\ H_2}{2.02\ g\ H_2} \times \frac{2\ mol\ H_2O}{2\ mol\ H_2} \times \frac{18.02\ g\ H_2O}{1\ mol\ H_2O} = 178\ g\ H_2O$$

178 grams of water can be produced from 20.0 g H_2, which is more than we need to produce 40.0 grams. Therefore, oxygen must limit.

$$(2)\ \ 40.0\ gH_2O \times \frac{1\ mol\ H_2O}{18.02\ g\ H_2O} \times \frac{2\ mol\ H_2}{2\ mol\ H_2O} \times \frac{2.02\ g\ H_2}{1\ mol\ H_2} = 4.48\ g\ H_2$$

Only 4.48 grams of hydrogen gas are needed to produce 40.0 g of water. Because we start with more hydrogen than this, oxygen must be the limiting reactant.

+3 points total

c. Determine the exact mass of oxygen needed to form 40.0 grams of water. Show your work.

+1 find moles water

$$40.0\ gH_2O \times \frac{1\ mol\ H_2O}{18.02\ g\ H_2O} \times \frac{1\ mol\ O_2}{2\ mol\ H_2O} \times \frac{32.0\ g\ O_2}{1\ mol\ O_2} = \mathbf{35.5\ g\ O_2}$$

+1 use mole ratio

+1 numerical answer**

+3 points total

Scenario 2: Aqueous sodium chloride reacts with aqueous silver nitrate ($AgNO_3$).

d. Give the balanced equation for this reaction, including phases. Note that you will need to determine the products for this reaction.

+1 reactants

+1 products

$NaCl(aq) + AgNO_3(aq) \rightarrow AgCl(s) + NaNO_3(aq)$

+1 balance and phases

+3 points total

A beaker containing 20.0 mL of a 2.00 M aqueous solution of sodium chloride is mixed with 100.0 mL of a 1.00 M aqueous solution of silver nitrate. In this scenario, the sodium chloride was limiting.

e. Explain in words how you know sodium chloride had to be limiting. In your explanation, be sure to compare the starting amount of sodium chloride with the amount needed to completely react with the silver nitrate. Support your answer with calculations.

+2 points for fully coherent explanation

+1 mathematical support

Sodium chloride had to be limiting. Because the reaction requires a 1:1 ratio of sodium chloride to react with the silver nitrate, we need equal moles of both to fully react. We have 0.100 mol of silver nitrate (using 1.00 M = x mol/.100 L) and we have only 0.040 mol sodium chloride (using 2.00 M = x mol/.020 L). Therefore, we do not have all the sodium chloride needed to completely react with the silver nitrate.

+3 points total

f. Determine the exact mass of precipitate which can be formed when this amount of silver nitrate and sodium chloride react. Show your work.

Using a BCA table (which is not the only way to solve this):

+1 using limiting reactant correctly

	$NaCl(g)$ +	$AgNO_3(aq)$ →	$AgCl(s)$ +	$NaNO_3(aq)$
B	**0.040**	**0.100**	**0**	**0**
C	**-0.040**	**-0.040**	**+0.040**	**0.040**
A	**0**	**0.060**	**0.040**	**0.040**

+1 moles of product

+1 mass product**

$$0.040\ mol\ AgCl \times \frac{143.4\ g\ AgCl}{1\ mol\ AgCl} = \mathbf{5.73\ g\ AgCl}$$

****Continuation credit is possible. If the answer to parts a and d were incorrect but they used them correctly in the following parts, full credit with wrong numbers is still possible.**