CHEMISTRY 101
Hour Exam II
October 27, 2020
Leveritt/McCarren

Name _______KEY___________________

Signature ___________________________

Section _____________________________

"Real change, enduring change, happens one step at a time." – Ruth Bader Ginsburg

This exam contains 30 questions. The first 15 questions are multiple choice questions. The remaining questions consist of two separate larger problems divided up into parts that link together. You may need to explain, calculate, or show work for answers. Please be sure to complete all questions.

1-15	(30 pts.)	_________
19-23	(15 pts.)	_________
24-30	(15 pts.)	_________
Total	(60 pts.)	_________

Useful Information:

1 L = 1000 mL (exactly)

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

PV = nRT

R = 0.08206 L·atm/mol·K

K = °C + 273

$N_A = 6.022 \times 10^{23}$ = 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.

Part 1: Multiple Choice

1. Liquid benzene (C_6H_6) decomposes to form solid carbon and hydrogen gas. What is the sum of coefficients when this equation is balanced in standard form with lowest whole number coefficients?
   a. 3
   b. 7
   c. 8
   d. 9
   e. **10**

2. What is **true** about a balanced equation?
   a. The left side of a balanced equation shows how many particles are present in the reaction container before the reaction begins.
   b. The ratios between the coefficients of a reactant and a product in the balanced equation show how many of each product forms when a particular amount of reactant is consumed.
   c. The subscript next to each element symbol does **not** need to the same on the left side and right side of a balanced chemical equation.
   d. All three of the above (a-c) are true.
   e. **Two of the above (a-c) are true.**

Consider the balanced equation before for the reaction of methane gas with chlorine gas to produce carbon tetrachloride and hydrochloric acid. Use this balanced equation to answer the next two questions.

$$CH_4(g) + 4Cl_2(g) \rightarrow CCl_4(g) + 4HCl(aq)$$

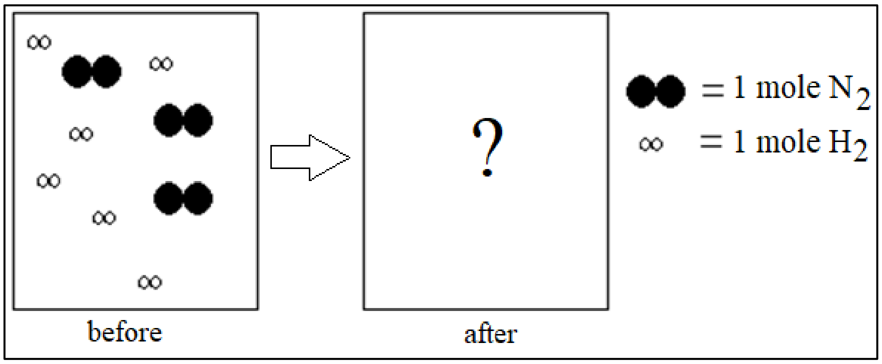
3. How many moles of methane gas are needed to react with 4.0 moles of chlorine gas?
   a. 0.25 moles
   b. 0.50 moles
   c. **1.0 moles**
   d. 2.0 moles
   e. 4.0 moles

4. What mass of hydrochloric acid (HCl) is formed when 1.54 grams of carbon tetrachloride are also formed?
   (Note: molar mass of CCl_4 = 153.82 g/mol, molar mass of HCl = 36.46 g/mol)
   a. 0.100 grams
   b. 0.400 grams
   c. 0.911 grams
   d. **1.46 grams**
   e. 225 grams

5. Consider the following reaction:

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

The image below shows substances present in the reaction container before the reaction.



What is present in the container after the reaction?

a. 2 moles NH_3 and 1 mole N_2
b. <u>4 moles NH_3 and 1 mole N_2</u>
c. 2 moles NH_3 and 3 moles H_2
d. 4 moles NH_3 and 3 moles H_2
e. 4 moles NH_3 only

6. Recall the reaction between hydrogen and oxygen gases as we have seen in lecture before according to the balanced equation below:

$$\mathbf{2H_2 + O_2 \rightarrow 2H_2O}$$

Equal **<u>masses</u>** of hydrogen and oxygen gases react.

Your friend says that oxygen is the limiting reactant in this situation. Is your friend correct? Choose the best answer and explanation.

a. *Yes*: The reactant with the larger molar mass is typically limiting.
b. <u>*Yes*: More than twice as many moles of hydrogen gas than oxygen gas are present.</u>
c. *It depends*: the limiting reactant changes based on the exact equal masses of hydrogen and oxygen that are used.
d. *No*: Hydrogen gas has a larger coefficient than oxygen, so hydrogen gas is limiting.
e. *No*: Fewer moles of hydrogen are present in the container before the reaction, so hydrogen limits.

7. You have an unknown aqueous solution "X" that you mix with several reagents. What is solution X? Use the information below to identify it.

- An acid-base reaction occurs when solution X is mixed with sodium hydroxide.
- A precipitate forms when solution X is mixed with lead(II) nitrate.
- **No** precipitate forms when solution X is mixed with barium nitrate.

a. K_3PO_4
b. Na_2CO_3
c. HCl
d. H_2SO_4
e. HNO_3

8. Hydrobromic acid (HBr) and the strong base calcium hydroxide react to form liquid water and aqueous calcium bromide through the following molecular equation:

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

What is the **complete ionic** equation for this reaction?
a. $2HBr(aq) + Ca(OH)_2(aq) \rightarrow 2H_2O(l) + CaBr_2(aq)$
b. $\mathbf{2H^+(aq) + 2Br^-(aq) + Ca^{+2}(aq) + 2OH^-(aq) \rightarrow 2H_2O(l) + Ca^{+2} + 2Br^-(aq)}$
c. $2H^+(aq) + 2Br^-(aq) + Ca^{+2}(aq) + (OH)_2^-(aq) \rightarrow 2H_2O(l) + Ca^{+2} + Br_2^-(aq)$
d. $2H^+(aq) + 2Br^-(aq) + Ca^{+2}(aq) + 2OH^-(aq) \rightarrow 2H_2O(l) + CaBr_2(aq)$
e. $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

9. Which of the following calcium hydroxide solutions will neutralize (completely react with) 1.0 L of 1.00 M hydrobromic acid? Use the balanced equation above to help you answer.
a. 1.00 L of 0.500 M $Ca(OH)_2$
b. 0.500 L of 1.00 M $Ca(OH)_2$
c. 2.00 L of 0.250 M $Ca(OH)_2$
d. None of the three combinations will neutralize the hydrobromic acid.
e. All three of the combinations will neutralize the hydrobromic acid.

10. Refer to the table below which represents combinations of aqueous solutions similar to those which you observed in the precipitation reactions video. How many of the following combinations are expected to produce precipitates? Assume that all reactants are in the aqueous phase.

	KNO_3	$NaCl$
$(NH_4)_2SO_4$		
Na_2S		

a. <u>0 (None of the combinations result in the formation of a precipitate.)</u>
b. 1
c. 2
d. 3
e. 4 (All four of the combinations result in the formation of a precipitate.)

11. Consider a 100.0 mL solution of 2.00 M sodium chloride. This solution is left alone on the counter, uncovered for three days. After those three days, water evaporates from the solution and as a result, the volume of the solution is now measured to be 50.0 mL. How do the **<u>moles of solute</u>** in the final solution compare to the moles of solute in the initial solution? Choose the answer which best fills in the blank below.

The moles of solute in the solution are ________________________ what they were before the solution was left out.

a. greater than double
b. double
c. <u>the same as</u>
d. half
e. less than half

12. How much water should be <u>added</u> to 100.0 mL of a 2.00 M solution of sodium chloride to reduce its concentration to 0.750 M?
a. 50 mL water
b. 150 mL water
c. <u>167 mL water</u>
d. 267 mL water
e. 300 mL water

Recall the lab experiment in which you observed several balloons inflating after reacting two different acids with sodium bicarbonate (baking soda). One of the reactions you saw took place below between the baking soda and sulfuric acid (H_2SO_4).

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

In the lab activity, you saw that various amounts of sodium bicarbonate and sulfuric acid were combined in quantities similar to those on the table below. Finish filling in the table, and use it to answer the next three questions.

Trial	**Moles H_2SO_4**	**Moles $NaHCO_3$**	**Moles CO_2 Produced**	**Limiting Reactant**
1	0.400	0.100		
2	0.300	0.200		
3	0.200	0.300		
4	0.100	0.400		

13. Consider trial #1, in which 0.400 moles of H_2SO_4 react with 0.100 moles of $NaHCO_3$. How many moles of excess reactant are leftover after this reaction?
    - **a. <u>0.350 moles</u>**
    - b. 0.300 moles
    - c. 0.250 moles
    - d. 0.200 moles
    - e. 0.100 moles

14. Consider trial #4, in which 0.100 moles of H_2SO_4 react with 0.400 moles of $NaHCO_3$. What volume of carbon dioxide gas can be produced at standard pressure (1.0 atm) and a temperature of 25.0 degrees Celsius?
    - a. 9.78 L
    - **b. <u>4.89 L</u>**
    - c. 2.45 L
    - d. 0.100 L
    - e. 0.204 L

15. Of these four trials, which combination is expected to result in the largest balloon?
    - a. Trial 1
    - b. Trial 2
    - **c. <u>Trial 3</u>**
    - d. Trial 4
    - e. Balloons in trials 3 and 4 are expected to be the same size.

Part 2: Free Response

16. Aqueous lead(II) nitrate reacts with aqueous sodium chloride and forms a precipitate according to the balanced molecular equation below.

$$\mathbf{Pb(NO_3)_2(aq) + 2NaCl(aq) \rightarrow PbCl_2(s) + 2NaNO_3(aq)}$$

Give the balanced net ionic equation for this reaction. You do not need to worry about proper formatting of any superscripts and subscripts, but please make sure that charges are included if the you are showing an ion. You do not need to include phases.

(Example: The aqueous calcium ion could be represented as Ca+2.)

+4 total

Net: **$Pb^{+2}(aq) + 2Cl^{-}(aq) \rightarrow PbCl_2(s)$**

+1 +1 +1 +1 balanced

***Can get 1 out of 4 points for putting complete ionic instead.

17. 200.0 mL of a 0.100 M lead(II) nitrate solution is required to react with exactly 100.0 mL of a NaCl solution. What is the concentration of the sodium chloride solution?

Computer graded +2

<u>0.400 M NaCl</u>

$$M = \frac{mol}{L} \qquad 0.100\ M\ Pb(NO_3)_2 = \frac{x\ mol}{.200\ L} \qquad x = .0200\ mol\ Pb(NO_3)_2$$

$$.0200\ mol\ Pb(NO_3)_2 \times \frac{2\ mol\ NaCl}{1\ mol\ Pb(NO_3)_2} = .0400\ mol\ NaCl$$

$$\frac{.0400\ mol\ NaCl}{.100\ L} = 0.400\ M\ NaCl$$

18. What is the **<u>mass of precipitate</u>** formed when these lead(II) nitrate and sodium chloride solutions react?

Computer graded +2

<u>5.56 g $PbCl_2$</u>

$$.0200\ mol\ Pb(NO_3)_2 \times \frac{1\ mol\ PbCl_2}{1\ mol\ Pb(NO_3)_2} \times \frac{278.1\ g\ PbCl_2}{1\ mol\ PbCl_2} = 5.56\ g\ PbCl_2$$

19. After the reaction, which ions remained present in the solution?

Computer graded +1

- Nitrate ions only
- **Nitrate and sodium ions**
- Nitrate, sodium, and lead(II) ions
- Nitrate, sodium, and chloride ions
- Nitrate, sodium, lead(II), and chloride ions

+2 total

20. Explain your answer to the previous question.

+1

Sodium and nitrate ions are spectators, so they are not used up in the reaction to form the precipitate. Therefore, they are left in the solution after the reaction because all the other ions are completely used up in forming the precipitate.

+1

21. What was the concentration of the **nitrate ions** present after this reaction?

Computer graded +1

0.133 M

22. Explain your answer and/or show all relevant work in the space below.

+3 total

+1

Moles of nitrate ions:

$$0.100\ M = \frac{x\ mol\ Pb(NO3)_2}{.200\ L}$$

$$= .0200\ mol\ Pb(NO_3)_2 \times \frac{2\ mol\ NO_3^-}{1\ mol\ Pb(NO_3)_2} = .0400\ mol\ NO_3^-$$

+1

Total volume = 200.0 mL + 100.0 mL = 300.0 mL = 0.300 L

+1

Concentration: $M = \frac{mol}{L} = \frac{.0400\ mol\ NO_3^-}{.300\ L} = 0.133\ M\ NO_3^-$

Nitrous oxide (NO) is a colorless, odorless gas which reacts quickly upon exposure to oxygen gas to form some product containing both nitrogen and oxygen according to the incomplete equation below.

$$NO(g) + O_2(g) \rightarrow \text{Product}$$

Consider a mixture of nitrous oxide and oxygen gas in a flexible container.

- ***Before*** the reaction, 180 grams of nitrous oxide and 192 grams of oxygen gas were present in a flexible container.
- ***After*** the reaction, some product formed, and 96.0 grams of oxygen gas were leftover.

	Substances Present		
	NO	O_2	Product
Before Reaction	180 g	192 g	0 g
After Reaction	0 g	96.0 g	????

23. What is the mass of the product formed?

276 grams

Computer graded +2

needed to use mass conservation: 180 g + 192 g before = 372 g total

372 g total after – 96.0 g O_2 = 276 grams product

24. Give the total number of moles of gas (NO and O_2 together) present in the container **before** the reaction.

12 moles

Computer graded +2

$$180\ g\ NO \times \frac{1\ mol\ NO}{30.0\ g\ NO} = 6.0\ mol\ NO$$

$$192\ g\ O_2 \times \frac{1\ mol\ O_2}{32.0\ g\ O_2} = 6.0\ mol\ O_2$$

$$6.0\ mol\ NO + 6.0\ mol\ O_2 = 12.0\ mol\ total$$

25. **After** the reaction, there were 9.0 total moles of gas present in the container. How many moles of product formed?

6 moles

Computer graded +2

$$96.0\ g\ O_2 \times \frac{1\ mol\ O_2}{32.0\ g\ O_2} = 3.0\ mol\ O_2$$

$$9.0\ moles - 3.0\ moles\ O_2 = 6.0\ moles\ product$$

26. Use a BCA table as well as your answers from questions 24 and 25 to determine the lowest whole number coefficients for each of the terms in the balanced equation.

Computer graded +1

a. NO **2**
b. O_2 **1**
c. Product **2**

27. Explain how you found your answer to the previous question.

+2 total

Using the change row of the BCA table, we see that these are in the same ratios as the coefficients in the balanced equation. Because the change row showed 6:3:6, the coefficients are 2:1:2 in simplest form.

28. Give the formula of the product formed.

Computer graded +2

NO2

Computer should also accept O2N, NOO, ONO, and OON.

****Give 1 out of 2 points for 2NO2.

29. This reaction occurred in a flexible container at a constant temperature. Before the reaction, the container had a volume of 20.0 liters. What is the new volume of the container after the reaction?

Computer graded +2

15.0 L

30. Explain your answer to the previous question, including showing all relevant work.

Temperature and pressure are constant, therefore only moles and volume change.

+1

We can use the equation $V_1/n_1 = V_2/n_2$.

Before the reaction, there were 12 moles of gas (question #24).

+2 total

After the reaction, there were 9.0 moles of gas (question #25).

+1

Therefore: 20.0 L/12.0 mol = V_2/9.0 moles

V_2 = 15.0 L (which makes sense – we have ¾ the moles so we end up with ¾ the volume.