CHEMISTRY 101
Hour Exam II
April 1, 2025
Dr. E. McCarren

Name _____KEY_____

Signature _____

Section _____

**Why should you avoid the stairs on April Fool's Day? Because they're always up to something.**

This exam contains 17 questions on 9 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).

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

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

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.

**Section 1: Multiple Choice**

1. Which of the following is **false** related to balanced equations?
    a. Subscripts give the number of atoms of an element in a given molecule.
    b. **Coefficients give the number of molecules of each substance present in the container before and after a reaction occurs.**
    c. Coefficients can be used to compare the number of moles of a given substance needed to react with moles of another substance.
    d. The right side of a balanced equation shows the substances formed as a result of the reaction.
    e. The left side of a balanced equation shows the identity of substances that will react.

2. Consider the unbalanced combustion reaction shown below. What is the sum of coefficients when this equation is balanced in standard form with lowest whole number coefficients?

$$\mathbf{C_2H_6 + O_2 \rightarrow CO_2 + H_2O}$$

    a. 8
    b. 9
    c. 10
    d. 18
    e. **19**

Consider the balanced equation below which shows the reaction between magnetite ($Fe_3O_4$) and hydrogen gas to produce molten iron and water vapor. Use this equation to answer the next two questions.

$$\mathbf{Fe_3O_4(}\boldsymbol{s}\mathbf{) + 4H_2(}\boldsymbol{g}\mathbf{) \rightarrow 3Fe(}\boldsymbol{l}\mathbf{) + 4H_2O(}\boldsymbol{g}\mathbf{)}$$

3. How many moles of iron are produced when 8.0 moles of hydrogen gas react with sufficient $Fe_3O_4$?
    a. 2.0 moles
    b. 3.0 moles
    c. 4.0 moles
    d. **6.0 moles**
    e. 8.0 moles

4. How moles of $Fe_3O_4$ are needed to produce 27.0 grams of water?
    a. **0.375 moles**
    b. 1.50 moles
    c. 6.00 moles
    d. 6.75 moles
    e. 1,390 moles

Carbon monoxide reacts with hydrogen gas to form methanol ($CH_3OH$) according to the balanced equation below. Use this balanced equation to answer the next two questions.

$$\mathbf{CO(g) + 2H_2(g) \rightarrow CH_3OH(g)}$$

In one situation, 34.8 grams of CO react with 18.2 grams of hydrogen gas.

5. What mass of product is formed?
    a. 1.24 grams
    b. 4.50 grams
    c. 9.10 grams
    d. **39.7 grams**
    e. 144 grams

6. What mass of excess reactant is left over?
    a. 6.53 grams
    b. 7.76 grams
    c. **13.1 grams**
    d. 15.6 grams
    e. 25.7 grams

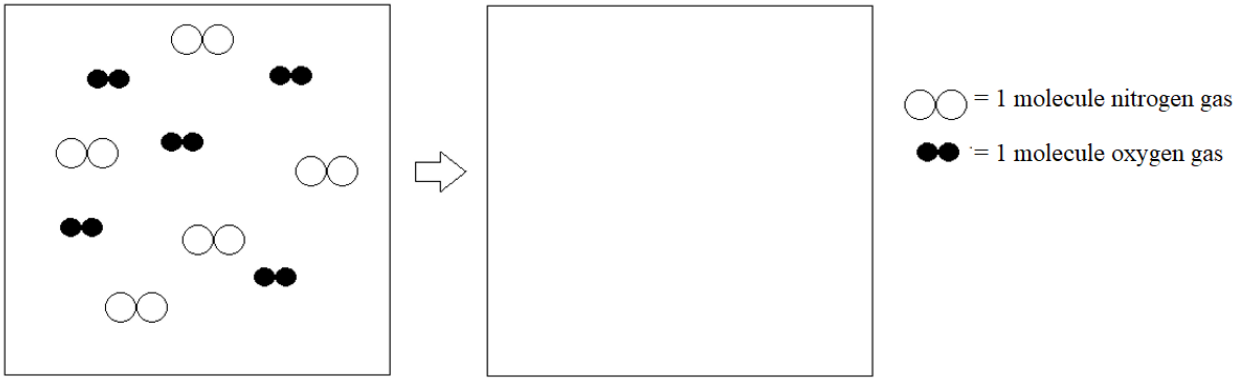
7. Consider two aqueous solutions of sodium chloride, labeled A and B. Solution A has the same concentration as solution B. Which is possible regarding the two solutions?
    a. It is possible that solution A and solution B have the same volume.
    b. It is possible that solution A has a greater volume than solution B.
    c. It is possible that solution B has a greater volume than solution A.
    d. Two of the options above (a. – c.) are possible.
    e. **All three of the options above (a. – c. ) are possible.**

8. An aqueous solution was created by dissolving 10.0 grams of calcium carbonate and adding enough water so that the volume of the solution was 100.0 mL. What is the concentration of the solution? (Note: molar mass $CaCO_3$ = 100.0 g/mol)
    a. $1.0\times10^{-5}$ M
    b. 0.100 M
    c. **1.00 M**
    d. 10.0 M
    e. 100.0 M

Consider the drawing below in which five molecules of $N_2$ and five molecules of $O_2$ are represented. The nitrogen and oxygen gases react to form a single product which consists of nitrogen and oxygen according to the unbalanced equation below. Assume x and y represent whole numbers between 1 and 10.

$$\mathbf{N_2 + O_2 \rightarrow N_xO_y}$$

Use the information given in this problem to answer the next two questions.




9. After this reaction, there are two molecules of product formed and three molecules of nitrogen gas left over. What is the identity of the product?
   a. $N_3O_2$
   b. NO
   c. $N_2O$
   d. $NO_2$
   e. **$N_2O_5$**

10. How do the total number of atoms and the total number of molecules before the reaction compare to the total number of atoms and molecules after the reaction? Choose the option which best fills in the blanks below.

    - ***The total number of atoms before the reaction is _____ the total number of atoms after the reaction.***
    - ***The total number of molecules before the reaction is _____ the total number of molecules after the reaction.***

    a. equal to; equal to
    b. **equal to; greater than**
    c. less than; less than
    d. greater than; greater than
    e. less than; equal to

11. Recall the lab activity in which you observed combinations of aqueous solutions, some of which formed precipitates. The table below is similar to the one you saw in lab in which multiple aqueous solutions are combined.

| | **$K_2SO_4$** | **$BaCl_2$** |
|---|---|---|
| **$Ca(NO_3)_2$** | | |
| **$Na_2CO_3$** | | |

Based on the solubility rules and the reactants in the table, for how many of the combinations is a precipitate expected to form?

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

12. Consider the reaction between aqueous solutions of strontium nitrate and potassium phosphate. A precipitate forms in this reaction. What is the formula of the precipitate?
    a. $SrPO_4$
    b. **$Sr_3(PO_4)_2$**
    c. $KNO_3$
    d. $K_3(NO_3)_2$
    e. $Sr_2(PO_4)_3$

***Please go on to the next page.***

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 occurred between baking soda and sulfuric acid according to the balanced equation below.

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

In the table below, the $H_2SO_4$ reacted with baking soda to inflate a series of three balloons each full of carbon dioxide. Assume a greater number of moles of carbon dioxide produced corresponds to a larger inflated balloon. Fill in the table, determining the moles of carbon dioxide produced with the combinations of reactants provided for Trials 1, 2, and 3. Use this information to answer the next three questions.

| Trial | Moles $H_2SO_4$ | Moles $NaHCO_3$ | Moles $CO_2$ produced |
|---|---|---|---|
| 1 | 0.100 | 0.300 | ? |
| 2 | 0.200 | 0.200 | ? |
| 3 | 0.300 | 0.100 | ? |

13. How many moles of carbon dioxide were produced when the reaction in Trial 3 occurred?
    a. **0.100 mol**
    b. 0.200 mol
    c. 0.300 mol
    d. 0.400 mol
    e. 0.500 mol

14. How does the size of the inflated balloon in Trial #1 compare to the size of the inflated balloon in Trial #2?

    ***The size of the balloon in Trial #1 is _____ the size of the balloon in Trial #2.***
    a. less than half
    b. half
    c. **equal to**
    d. double
    e. greater than double

15. The balloon in Trial #3 is predicted to be smaller than the balloon in Trial #1. What is the minimum amount of additional baking soda that would need to be added to Trial #3 so that both balloons in Trial #1 and Trial #3 inflate to the same size?
    a. **0.100 mol baking soda**
    b. 0.200 mol baking soda
    c. 0.300 mol baking soda
    d. 0.400 mol baking soda
    e. 0.500 mol baking soda

**Section 2: Free Response**

16. Consider the reaction between solid magnesium and hydrochloric acid (HCl) to form aqueous magnesium chloride and hydrogen gas.

+4 points total

a. Complete the balanced equation for this reaction by providing the formulas of the products along with proper phases. Use this balanced equation to answer parts b. and c.

**$Mg(s) + 2HCl\ (aq) \rightarrow \underline{MgCl_2(aq) + H_2(g)}$**

+2 coefficients of 1/not labeled

+1 +1

+5 points total

You wish to form 0.500 L of hydrogen gas at a pressure of 1.0 atm and a temperature of 25.0°C.

b. You use a 0.100 M HCl solution to form this volume of hydrogen gas. What volume of the HCl solution is required? Give your answer in units of milliliters. Show your work.

+1 **PV = nRT**

**(1.0 atm)(0.500 L) = n (.08206)(25°C + 273)**

+1 **n = .0204 mol $H_2$ gas**

+1 $.02044\ mol\ H_2 \times \frac{2\ mol\ HCl}{1\ mol\ H_2} = .0409\ mol\ HCl$

+1 $0.100\ M\ HCl = \frac{.0409\ mol\ HCl}{x\ L}$

+1 **x = .409 L or <u>409 mL</u>**

+3 points total

c. What mass of magnesium is required to form this volume of hydrogen gas? Show your work.

$$.02044\ mol\ H_2 \times \frac{1\ mol\ Mg}{1\ mol\ H_2} \times \frac{24.31\ g\ Mg}{1\ mol\ Mg} = 0.497\ g\ Mg$$

+1 +1 +1

***Please go on to the next page.***

17. For this question, consider two separate reactions, both of which we have seen in class this semester. Use the information given in the problem to answer each of the questions related to the reactions.

**Reaction 1**

Hydrogen gas and oxygen gas react to form liquid water according to the balanced equation below.

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

**Equal masses** of hydrogen and oxygen gas react.

+5 points total

a. Which is the limiting reactant? Identify the limiting reactant and show your work.

+1 **Oxygen is the limiting reactant.**

**Select equal masses and convert to moles:**

+1 $$100.0\ g\ O_2 \times \frac{1\ mol\ O_2}{32.0\ g\ O_2} = 3.125\ mol\ O_2$$

+1 $$100.0\ g\ H_2 \times \frac{1\ mol\ H_2}{2.02\ g\ H_2} = 49.5\ mol\ H_2$$

**Use a BCA table or other method of determining what is limiting:**

+2

| | $2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$ | | |
|---|---|---|---|
| **B** | **49.5** | **3.125** | **0** |
| **C** | **-6.25** | **-3.125** | **+6.25** |
| **A** | **43.25** | **0** | **6.25** |

+4 points total

b. Explain in words how you know which reactant was limiting by comparing how much of one reactant is needed to completely use up the other reactant. Be specific and provide numerical evidence from your answer in part a. to help answer the question.

+2 explain

+2 numerical support which makes sense

**Oxygen was limiting because there is more than enough hydrogen present to use up the oxygen. If we choose 100.0 grams of both substances, this means that there were 3.125 moles of oxygen. To use this up, only 6.25 moles of hydrogen gas were required, and we started with 49.5 moles of hydrogen, which was much more than we needed. Therefore, hydrogen was excess because we had more than we needed, and oxygen was limiting because we did not have enough to use up all the hydrogen**

**Reaction 2**

A neutralization reaction occurs between aqueous sulfuric acid and aqueous potassium hydroxide according to the balanced equation shown below.

$$H_2SO_4(aq) + 2KOH(aq) \rightarrow 2H_2O(l) + K_2SO_4(aq)$$

The sulfuric acid solution has a volume of 2.0 L and a concentration of 2.0 M, and the potassium hydroxide solution has a volume of 5.0 L and a concentration of 2.0 M.

+5 points total

c. Which **three** ions are left in the solution after the reaction? Select those ions that remain in the solution. Show any work in the space below.

- ★ Sulfate ion
- ☐ Hydrogen ion
- ★ Potassium ion
- ★ Hydroxide ion

+2 fully correct, no partial credit

+1 find moles

$$2.0\ M = \frac{x\ mol}{2.0\ L} \quad x = 4.0\ mol\ H_2SO_4$$

$$2.0\ M = \frac{x\ mol}{5.0\ L} \quad x = 10.0\ mol\ KOH$$

+2 find limiting

| | $H_2SO_4(aq) + 2KOH(aq) \rightarrow 2H_2O(l) + K_2SO_4(aq)$ | | | |
|---|---|---|---|---|
| **B** | **4.0** | **10.0** | **0** | **0** |
| **C** | **-4.0** | **-8.0** | **+8.0** | **+4.0** |
| **A** | **0** | **2.0** | **8.0** | **4.0** |

+4 points total

d. Explain in words how you know which ions remain in the solution. As part of your explanation, you should mention each of the four ions above, stating whether each of the four ions above was limiting, excess, or a spectator ion, and how you knew this based on your work in part c.

+2* **Sulfate and potassium were spectator ions because they were not involved in the reactant at all – they are aqueous both before and after the reaction.**

+1* **The hydrogen ion was limiting because it was completely used up in the acid base reaction (visible in the BCA table above) and was also involved in forming the production.**

+1* **The hydroxide ion was excess because some, but not all, of it was used up in forming the water product (there is still some KOH leftover after the reaction as shown in the BCA table)**

*Explanation must also be correct to earn the point.