CHEMISTRY 101
Hour Exam I
September 19, 2023
McCarren

Name _____KEY_____

Signature _____

Section _____

"Each person must live their life as a model for others." – Rosa Parks

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	(15 pts.)	_____
17	(15 pts.)	_____
Total	(60 pts)	_____

Useful Information:

PV = nRT

K = °C + 273

R = 0.08206 L•atm/mol•K

Density = mass / volume

Avogadro's number = 6.022×10^{23}

1 L = 1000 mL

1 atm = 760. torr

Assume atmospheric pressure is 1.00 atm (unless explicitly told otherwise).

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

Section 1: Multiple Choice

+2 points each question

1. The distance between Champaign, IL and Bloomington, IL is about 50 miles. If your car has a gas mileage of 35 miles per gallon and the price of gas is $3.50 per gallon, about how many 50 mile trips will you be able to make between the two cities with $50.00 worth of gas?
    a. 50 trips
    b. 25 trips
    c. 15 trips
    d. **10 trips**
    e. 5 trips

2. Is the statement below true or false? Select the best answer and explanation.

    "A molecule is always also considered to be a compound."

    a. ***False:* Molecules can consist only of atoms of the same element, but compounds must consist of more than one element.**
    b. *False:* Molecules can consist of one single unconnected atom, but compounds must have at least two atoms bonded.
    c. *False:* Molecules and compounds cannot share the same chemical composition.
    d. *True:* Molecules and compounds both contain at least two atoms connected together.
    e. *True:* Molecules and compounds are both ways of describing arrangements of particular elements.

3. What is the percent by mass of nitrogen in dinitrogen tetrahydride?
    a. 96.6%
    b. 93.3%
    c. **87.4%**
    d. 82.3%
    e. 77.8%

4. Each of the compounds below includes at least one polyatomic ion. For which compound is the formula written **incorrectly**?

	Name	**Formula**
a.	magnesium sulfate	$MgSO_4$
b.	**calcium carbonate**	**Ca_2CO_3**
c.	aluminum hydroxide	$Al(OH)_3$
d.	potassium phosphate	K_3PO_4
e.	ammonium nitrate	NH_4NO_3

5. Each of the compounds below includes names which require Roman numerals. For how many of the formulas are the compounds named **correctly**?

Formula	**Name**
Co_3P_2	cobalt(II) phosphide
Cu_3N	copper(I) nitride
PbS	lead(II) sulfide
$MnCl_2$	manganese(II) chloride

   a. **4 (All four of the names are correct.)**
   b. 3
   c. 2
   d. 1
   e. 0 (None of the names are correct.)

6. Which of the statements below is **true**?
   a. 6.022×10^{23} grains of rice is one mole of rice grains.
   b. 6.022×10^{23} atoms of carbon is one mole of carbon atoms.
   c. 6.022×10^{23} molecules of water is one mole of water molecules.
   d. **All of the above (a-c) are true.**
   e. Two of the above (a-c) are true.

7. What is the mass of 1.57 moles aluminum chloride?
   a. 84.0 grams
   b. 98.0 grams
   c. 154 grams
   d. 183 grams
   e. **209 grams**

8. There are 13 protons in the ion shown below. What is the number of neutrons and electrons in this species?

$$^{27}_{13}Al^{+3}$$

	Electrons	Neutrons
a.	13	27
b.	**10**	**14**
c.	16	13
d.	10	27
e.	16	14

9. Recall the lecture demonstration in which you saw a balloon get smaller after liquid nitrogen was poured onto it.

The room was initially at a temperature of about 25.0°C and the volume of the balloon was 400. mL. After the liquid nitrogen was poured onto the balloon, the balloon shrank to 150. mL. To what temperature was the balloon cooled?

a. -206 °C
b. **-161 °C**
c. 9.38°C
d. 112 °C
e. 496°C

10. If 2.71 **grams** argon gas occupies a volume of 4.21 liters, what volume will 1.29 moles of argon occupy at the same conditions?

a. 0.0208 L
b. 0.221 L
c. 2.00 L
d. 8.84 L
e. **80.1 L**

11. A sample of helium gas has volume 40.0 L at a pressure of 1.0 atm. The temperature of the gas is 300 K. How many moles helium gas are present?

a. 0.0109 mol
b. 0.615 mol
c. **1.62 mol**
d. 88.6 mol
e. 1,240 mol

You have a sealed, rigid 50.0 L container which consists of a mixture of equal masses of hydrogen and helium gases. Use this information to answer the next four questions.

12. How do the temperatures of the hydrogen and helium gas samples compare?

The temperature of the hydrogen gas is _____ the temperature of the helium gas.

a. one-quarter
b. half
c. **equal to**
d. double
e. four times

13. How do the volumes of the hydrogen and helium gas samples compare?

The volume of the hydrogen gas is _____ the volume of the helium gas.

a. one-quarter
b. half
c. **equal to**
d. double
e. four times

14. How do the number of moles of gas in the hydrogen and helium gas samples compare?

The number of moles of hydrogen gas present is _____ the number of moles of helium gas present.

a. one-quarter
b. half
c. equal to
d. **double**
e. four times

15. How do the partial pressures of the hydrogen and helium gas samples compare?

The partial pressure of the hydrogen gas sample is _____ the partial pressure of the helium gas sample.

a. one-quarter
b. half
c. equal to
d. **double**
e. four times

Section 2: Free Response

16. The questions below are separated into two parts related to the mole: counting atoms and empirical formula. Answer each question carefully and completely in the space below each question, being sure to show all of your work and explain where required.

Section 1: The Mole

+3 points total

a. Consider 10.0 g samples of copper, aluminum, and zinc. Which of the three samples has the greatest number of atoms? If more than one have the same greatest number of atoms, state this and explain. Show your work and/or explain your answer in the space below.

+1 aluminum

+2 coherent explanation or calculations

Multiple ways to explain. Of the three options given, the aluminum would have the greatest number of atoms because it has the lowest molar mass (lowest mass per atom) and therefore will have the greatest number of moles of atoms in 10.0 grams. It is also possible to calculate the number of moles or the number of individual atoms to solve this problem.

b. How many hydrogen atoms are present in 10.0 grams of water? Show work to support your answer.

+4 points total

+1 +1 +1

$$10.0\ g\ H_2O \times \frac{1\ mol\ H_2O}{18.02\ g\ H_2O} \times \frac{6.022 \times 10^{23} molecules\ H_2O}{1\ mol\ H_2O} \times \frac{2\ atoms\ H}{1\ molecule}$$

$$= \mathbf{6.68 \times 10^{23} atoms\ H}$$

+1

Section 2: Empirical and Molecular Formula

+3 points total

c. Can the empirical formula of a compound be the same as the molecular formula of a compound? State yes or no and then explain your answer in the space below. Provide an example to support your answer.

+1 yes

+1 explanation

+1 example

Yes, the empirical formula can be the same as the molecular formula of a compound because some compounds are already in their lowest whole number ratios of atoms. For example, the compound H_2O, water, cannot be simplified any further.

d. Give the empirical and molecular formulas of a compound containing only nitrogen and oxygen which is 69.6% oxygen by mass. The compound has a molar mass of 138.0 g/mol. Show your work in the space below. Be sure to label which formula is empirical and which is molecular.

Assume 100 grams. This means there are 69.6 g oxygen and 30.4 g nitrogen.

Then:

+5 points total

$$69.6\ g\ O \times \frac{1}{16.0\ g\ O} = \frac{4.35\ mol\ O}{2.17} \approx 2$$

+2 coherent work finding empirical formula

$$30.4\ g\ N \times \frac{1}{14.0\ g\ O} = \frac{2.17\ mol\ N}{2.17} \approx 1$$

+1 empirical

The empirical formula is NO_2.

The molar mass of this empirical formula is 46.0 g/mol.

+1 coherent work finding molecular formula

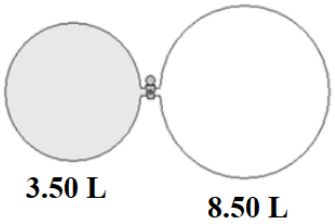
138 g/mol ÷ 46.0 g/mol = 3

+1 molecular

This means that the molecular formula is $(NO_2)*3$ or N_3O_6.

17. Consider "System A" below, which consists of a two-bulb container in which the bulbs are connected by a valve. The valve is closed so that gas is unable to move between the two bulbs.

System A



The left 3.50 L bulb currently holds a sample of helium gas at a temperature of 25.0°C and a pressure of 3.75 atm. The right bulb is a vacuum (i.e. it is empty).

+2 points total

a. The valve between the two bulbs is opened so that helium gas is able to move freely throughout both bulbs of the system. When this occurs, the pressure of the helium gas changes. When the valve is opened, do the pressure of gas, moles of gas, volume of gas, and temperature of gas in System A each increase, decrease, or remain constant? Fill in the table below with your answers for each variable.

+0.5 points each blank

Variable	**Increase, decrease, or remain constant?**
Pressure of helium gas	**Decrease**
Moles of helium gas	**Constant**
Volume of helium gas	**Increase**
Temperature of helium gas	**Constant**

+3 points total

b. *Why* does the pressure of the helium gas in the system change when the valve has been opened? Explain, providing an explanation regarding particle behavior in the table below. Your answer should include explaining information from part a.

+1 volume

+2 collisions and pressure

The moles of gas and the temperature of the gas remain constant. When the valve is opened between the two bulbs, the gas expands into both bulbs which increases the volume of the gas. This decreases the pressure because fewer particle collisions with the container walls are occurring.

c. What is the new pressure in system A after the valve has been opened? Show work.

+3 points total

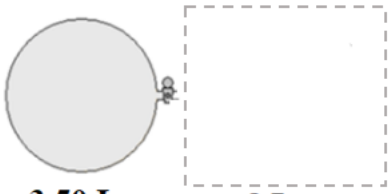
$P_1V_1 = P_2V_2$ (Note that V_2 is the volume of both bulbs combined.) +1

(3.75 atm)(3.50 L) = P_2(8.50 L + 3.50 L) +1 with proper volumes

P_2 = 1.09 atm +1

You have a gas in a new two-bulb container called "System B" shown below which contains an unknown monatomic gas. The valve is closed so that gas is unable to move between the two bulbs. The initial volume of the left bulb is 3.50 L and the right bulb's volume is unknown.

System B



The sample of gas has a mass of 3.61 g and a temperature of 25.0°C. The initial pressure in the left bulb is 1.25 atm and the right bulb is a vacuum (i.e. it is empty and contains no gas).

+4 points total

d. What is the identity of the monatomic gas in system B? Show work.

P = 1.25 atm
T = 25.0°C + 273 = 298 K +1 temperature
V = 3.50 L

PV = nRT
(1.25 atm)(3.50 L) = n(0.8206)(298 K) +1 finding moles
n = .179 moles

3.61 g/0.179 moles = 20.18 g/mol = <u>neon</u>

+1 +1

+3 points total

e. The valve between the two gases is opened and gas is able to move freely between the two bulbs. After opening the valve, the pressure in the entire system drops from 1.25 to 0.25 atm. What is the volume of the right bulb? Show work.

P_1 = 1.25 atm **V_1 = 3.50 L** **P_2 = 0.25 atm** **V_2 = ?**

+1 **$P_1V_1 = P_2V_2$**

(1.25 atm)(3.50 L) = (0.25 atm)(V_2)

+1 **V_2 = 17.5 L**

17.5 L – 3.50 L = <u>14.0 L</u>

+1