CHEMISTRY 202
Hour Exam I
September 21, 2023
Dr. D. DeCoste

Name ______________________________

Signature ___________________________

T.A. _______________________________

This exam contains 23 questions on 10 numbered pages. Check now to make sure you have a complete exam. You have two hours to complete the exam. Determine the **best** answer to the first 20 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 21, 22 and 23.

1-20	(60 pts.)	_____________
21	(20 pts.)	_____________
22	(20 pts)	_____________
23	(20 pts.)	_____________
Total	(120 pts)	_____________

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

$PV = nRT$

$R = 0.08206$ Latm/molK $= 8.3145$ J/Kmol

$K = °C + 273$

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

$$\upsilon_{rms} = \sqrt{\frac{3RT}{M}}$$

$$\lambda = \frac{1}{\sqrt{2}(N/V)(\pi d^2)}$$

$$Z_A = A\frac{N}{V}\sqrt{\frac{RT}{2\pi M}}$$

$$Z = 4\frac{N}{V}d^2\sqrt{\frac{\pi RT}{M}}$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

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, 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, and calcium hydroxide.
6. Consider sulfide, carbonate, and phosphate salts to be insoluble.

1. Which of the following contains the **greatest** percent by mass oxygen?

   a) Sodium bicarbonate
   b) Potassium phosphate
   c) Barium hydroxide
   d) Potassium nitrate
   e) Sodium sulfate

2. Which of the following is the closest estimation of the number of atoms that make up an adult human? 1 kg is about 2.2 lbs. on Earth.

   a) 10^{18} b) 10^{23} c) 10^{27} d) 10^{32} e) 10^{37}

3. Iron (Fe) reacts with oxygen gas to form iron(II) oxide and iron(III) oxide. You react 1.00 mole of iron with 20.0 g of oxygen gas to form a mixture of the oxides, with no leftover reactants. Determine the mass of iron(III) oxide produced.

   a) 35.9 g b) 39.9 g c) 71.9 g d) 75.9 g e) 79.9 g

4. You react **equal masses** of reactants together. For which of the following cases is oxygen gas **not** the limiting reactant?

   a) Reacting calcium metal with oxygen gas to produce calcium oxide.
   b) Reacting methane (CH_4) with oxygen gas to produce carbon dioxide and water.
   c) Reacting hydrogen and oxygen gases to produce water.
   d) Oxygen gas limits all of the reactions described above (a-c).
   e) Oxygen gas does not limit any of the three reactions described above (a-c).

5. You have a 100.0 g mixture of methane (CH_4) and oxygen gas, which react to produce carbon dioxide and water. What is the **maximum mass** of carbon dioxide that can be produced?

   a) 46.21 g b) 54.98 g c) 68.75 g d) 100.0 g e) More data required.

6. Consider aqueous solutions of barium nitrate and potassium hydroxide, each with the **same concentration** as measured in units of molarity. You mix 100.0 mL of the barium nitrate solution with the potassium hydroxide solution such that the concentration of the nitrate ions is **four times** that of the concentration of the barium ions in solution **after the reaction** is complete. What volume of potassium hydroxide solution was added?

   a) 16.7 mL b) 33.3 mL c) 50.0 mL d) 66.7 mL e) 100.0 mL

7. Consider 0.100*M* aqueous solutions of sodium chloride and silver nitrate. What volume of the 0.100*M* sodium chloride solution must be added to 100.0 mL of the 0.100*M* silver nitrate solution such that the concentration of the silver ions in the final solution is 0.0200*M*?

   a) 16.7 mL b) 33.3 mL c) 50.0 mL d) 66.7 mL e) 100.0 mL

8. When 100.0 mL of a 0.100*M* solution of magnesium nitrate is mixed with 100.0 mL of a 0.100*M* solution of sodium nitrate, what is the concentration of the nitrate ions?

a) 0.0500*M* b) 0.100*M* c) 0.150*M* d) 0.200*M* e) 0.300*M*

9. When solid potassium chlorate ($KClO_3$) is heated, the products are potassium chloride and oxygen gas. A 15.0 g sample of potassium chlorate is heated for a bit of time and the oxygen gas is collected in a balloon. The volume of the balloon is measured to be 3.14 L at 1.00 atm and 25ºC. Which of the following best describes the situation?

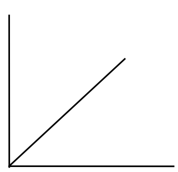
a) There is $KClO_3$ remaining after heating and 9.57 g of potassium chloride is produced.
b) There is $KClO_3$ remaining after heating and 9.12 g of potassium chloride is produced.
c) There is $KClO_3$ remaining after heating and 6.38 g of potassium chloride is produced.
d) All of the potassium chlorate was converted to potassium chloride and oxygen.
e) The data are incorrect. There was not enough oxygen produced to make a balloon that size at those conditions.

10. Consider a mixture of **equal masses** of helium (He) gas and neon (Ne) gas in a rigid vessel. Determine the ratio of:

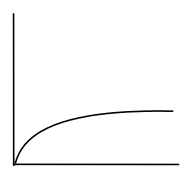
[collision frequency (Z_A) of He] : [collision frequency (Z_A) of Ne]
(for a given area, A, of the walls of each container)

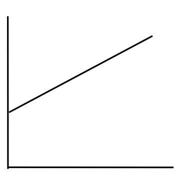
a) 0.4454 b) 1.000 c) 2.245 d) 5.042 e) 11.32

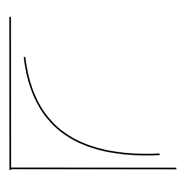
11-13. Indicate which of the graphs below best represents each plot described in questions 11, 12, and 13. Note: the graphs may be used once, more than once, or not at all.

a)


b)


c)


d)


e)


11. Change in momentum per impact (y) vs. T (x) for an ideal gas at constant V.

12. Collision frequency (Z_A) (y) vs. P (x) for an ideal gas at constant V and T.

13. Volume (y) vs. T (ºC) (x) for a sample of an ideal gas in a container fitted with a massless, frictionless piston.

14. Consider a sample of neon gas (Ne) in a rigid container at 3.14 atm. You add krypton gas (Kr) to the container at constant temperature until the density of the mixture is the same as the density of nitrogen gas. The conditions of pressure and temperature of the nitrogen gas are the same as the final mixture of neon and krypton. What is the **total pressure** in the container of neon and krypton?

a) 3.58 atm b) 4.76 atm c) 5.83 atm d) 6.28 atm e) 25.5 atm

15. You add equal masses of dry ice (solid carbon dioxide) and liquid nitrogen to a balloon and seal it. This system achieves room conditions (1.00 atm and 25ºC) after all of the dry ice sublimates and the liquid nitrogen boils. The final volume of the balloon is found to be 97.8 L. Determine the **mass of the dry ice** that was added to the balloon.

a) 43.6 g b) 68.5 g c) 108 g d) 137 g e) 144 g

16. Recall the lecture demonstration in which we reacted aqueous hexaaquacobalt(II) ions with concentrated hydrochloric acid, as represented by the following equation:

$$\underset{\text{(red)}}{Co(H_2O)_6^{2+}(aq)} + 4Cl^-(aq) \rightleftharpoons \underset{\text{(blue)}}{CoCl_4^-(aq)} + 6H_2O(l)$$

Which of the following best describe(s) and explain(s) the color of the system after adding water?

I. The solution turned red because water is part of a reactant ion.
II. The solution turned blue because water is part of a reactant ion.
III. The solution turned red because we added more product and so equilibrium shifted to the reactant side.
IV. The solution turned blue because we added more product and so equilibrium shifted to the product side.

a) I, III b) II, IV c) II d) III e) None of these.

17. The gas SO_3 decomposes to form $SO_2(g)$ and $O_2(g)$. You place a sample of pure SO_3 gas in an evacuated rigid steel container and record the pressure. You note that when the system reaches equilibrium at constant temperature, the pressure has increased by 40.0%. What percent of the SO_3 has decomposed at equilibrium?

a) 10.0% b) 20.0% c) 40.0% d) 60.0% e) 80.0%

18. A 100.1 g sample of solid calcium carbonate is placed in a 15.0-L evacuated rigid steel container. Calcium carbonate decomposes to produce solid calcium oxide and carbon dioxide gas. The reaction achieves equilibrium at 25ºC and the mass of solid remaining in the container is measured to be 60.48 g. Determine the value of the equilibrium constant, K_p, for the reaction written in standard form.

a) 0.645 b) 1.47 c) 8.10 d) 13.2 e) 22.0

19. In an evacuated, rigid steel container at constant temperature you react an equal number of moles of $PCl_3(g)$ and $Cl_2(g)$ so that the total pressure is 16.0 atm. The system reaches equilibrium according to the following chemical equation:

$$PCl_3(g) + Cl_2(g) \rightleftharpoons PCl_5(g)$$

After equilibrium is reached, you note that the partial pressures of all three gases are equal. Determine the value of the equilibrium constant, K_p, for the reaction as written above.

a) 0.0313 b) 0.0625 c) 0.125 d) 0.250 e) 1.00

20. The gases NH_3 (partial pressure = 5.0 atm) and O_2 (partial pressure = 5.0 atm) are placed in a steel rigid container. They react to equilibrium at constant temperature according to the following equation, for which $K_p = 1.0 \times 10^{18}$.

$$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g)$$

Determine the equilibrium pressure of $O_2(g)$.

a) 2.4×10^{-17} atm b) 1.2×10^{-11} atm c) 1.3×10^{-3} atm d) 6.5×10^{-3} atm e) 3.3×10^{-2} atm

21. For both portions of question 21, **show and explain** all work. Full credit is reserved for a **systematic approach to solving each problem**.

a. You have a binary ionic oxide that is 53.0% metal by mass. The compound has a molar mass that is less than 125 g/mol. With just this information and knowledge and understanding of fundamental chemical principles, provide the **formula and name** for this compound. If you believe there is more than one possible answer, please provide **all possible** formulas and names, and support your answers. **[10 points]**

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21. b. You pour 100.0 mL of a lead(II) nitrate solution into 100.0 mL of a silver nitrate solution such that the **percent by moles of lead(II) ions** is 11.1% of all ions in solution. You label this Solution A.

You add an excess of a potassium chloride solution to Solution A. You collect and dry all of the solid and find the sample to have a mass of 88.9g.

Determine the **concentration of the nitrate ions** in Solution A (that is, before the potassium chloride was added) in terms of **molarity**. **[10 points]**

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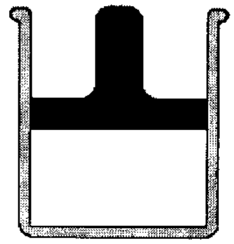
22. Consider a cylindrical container fitted with a massless, frictionless piston as shown below:



To this container, which is sitting in an environment at 1.000 atm and 587K, you add a mixture of methane (CH_4), propane (C_3H_8), and oxygen gases such that the original volume of the container is 120.4 L. Reactions are initiated (methane and propane each react with oxygen to produce carbon dioxide gas and water vapor), and when the reactions are run to completion, the product mixture (which includes oxygen gas) returns to 587K.

According to your measurements, the final density of the mixture is 89.28% of the initial density of the mixture. Determine the following:

- The **mole fraction of propane gas** in the original reactant mixture.
- The **range of possible mole fractions of methane gas** in the original reactant mixture.

Full credit is reserved for **showing all work** and **providing complete explanations** with a **correct and coherent general solution**. That is, your answer should not only include **equations and calculations**, but **explanations about what you are doing and why**. Make sure to **define any variables** and to **state and justify any assumptions**. Please use the next page if needed. **[20 points]**

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22. Continue work on this problem below, if needed.

23. The molecule borane (BH_3) is relatively unstable and will react with itself to form diborane (B_2H_6), a process known as dimerization. In a closed container, of course, the system will reach equilibrium, and it does so according to the following equation:

$$2BH_3(g) \rightleftharpoons B_2H_6(g)$$

Consider a container fitted with a massless, frictionless piston in a lab room at 1.00 atm and 25ºC. To this container you add borane gas until the volume of the container is 24.45 L. The system as written above reaches equilibrium at 25ºC. At this point the density of the gaseous mixture is 1.069 g/L.

Determine the value of the equilibrium constant, K_p, for this reaction at 25ºC.
Show and explain all work. **[12 points]**

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23. b. Suppose you have the system at equilibrium as seen in part a. You quickly add the inert gas argon (Ar) at 25ºC such that the gaseous mixture is 50% argon by moles (the borane and diborane do not have time to react at this point) and, after all of the argon has been added, the piston is locked into place. **Is the system still at equilibrium?** If you believe so, explain why adding argon gas does not affect the equilibrium position. If the believe that equilibrium was disturbed, when the system re-achieves equilibrium, **will the mole percent of argon gas be less than, greater than, or equal to 50%**?

Please provide support (conceptual and or quantitative) for your answers, along with a discussion of Q vs. K. **[8 points]**
