CHEMISTRY 202
Hour Exam I
September 25, 2025
Dr. D. DeCoste

Name ________**KEY**__________

Signature ____________________________

T.A. ________________________________

This exam contains 23 questions on 12 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.

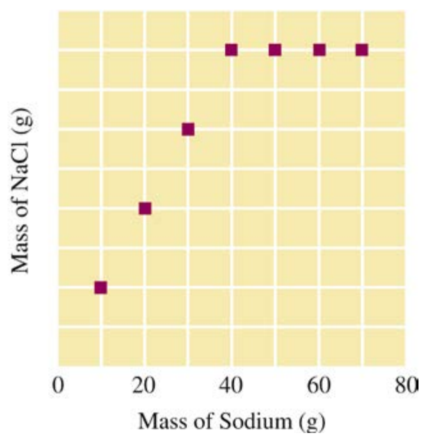
1. You are given five samples of the following compounds, and each sample contains the **same mass of oxygen**. Which of the samples has the **greatest total mass**?

   a) water
   b) calcium nitrate
   c) lithium hydroxide
   d) magnesium carbonate
   e) sodium phosphate

2. Substance AB_2 is 25.00% A by mass. Which of the following is 50.00% A by mass?

   a) A_3B_2 b) AB c) A_2B d) A_2B_3 e) A_4B_3

3. Consider an experiment with seven closed containers, each with equal masses of chlorine (Cl_2) gas. You add increasing 10.0g increments of masses of sodium metal to each of the containers (10.0 g to the first, 20.0 g to the second, etc. until 70.0 g to the seventh). After each reaction is complete (sodium metal reacts with chorine gas to produce the ionic compound sodium chloride), you measure the mass of product. The results are shown in the following graph:



   Determine the **total mass of sodium that remains** after the experiment is complete.

   a) 0 g b) 60.0 g c) 160.0 g d) 180.0 g e) 220.0 g

4. Imagine five separate equimolar (same number of moles) samples of the following hydrocarbons each reacting with an excess of oxygen gas to produce carbon dioxide and water. For which is there the **smallest difference in mass** between the maximum possible mass of carbon dioxide produced and the mass of the original sample of hydrocarbon?

   a) CH_4 b) C_2H_6 c) C_3H_8 d) C_7H_{16} e) $C_{12}H_{26}$

5. What mass of potassium carbonate is needed to produce 250.0 mL of a solution with the same concentration of potassium ions as a solution made by adding 1.00 mole of potassium chloride to enough water to make 1.00 L of solution?

   a) 12.4 g b) 17.3 g c) 34.6 g d) 51.9 g e) 69.1 g

6. The hydrogen oxygen balloon demo is a class favorite! In this reaction we mix hydrogen and oxygen gases together, and, upon reacting, fire, sound, and water are produced. Suppose we carry out the reaction such that the mass of water produced is **about half the mass** of the original mixture of hydrogen and oxygen gases. Which of the following mixtures would allow for this situation?

a) Equal masses of hydrogen and oxygen gases are reacted.
b) The mass ratio between hydrogen and oxygen gases is about 1:8.
c) We have about 25% more mass of hydrogen gas than oxygen gas.
d) We have about 75% more mass of oxygen gas than hydrogen gas.
e) Because mass is conserved this is impossible.

7. Mixing aqueous solutions of lead(II) nitrate and potassium iodide results in the formation of a beautiful yellow solid. Consider mixing 150.0 mL of 0.1250*M* of lead(II) nitrate with 150.0 mL of 0.1250*M* potassium iodide. Determine the concentration of the nitrate ion after the reaction is complete.

a) 0.01563*M* b) 0.03125 *M* c) 0.06250*M* d) 0.1250*M* e) 0.2500*M*

8. In lecture I mixed aqueous solutions of $AgNO_3$ and K_2CrO_4 (potassium chromate) to produce a blood red solid. In order to produce 10.0 g of solid, which of the following is the **minimum volume** of aqueous 0.500*M* $AgNO_3$ required?

a) 30.1 mL b) 60.3 mL c) 89.3 mL d) 121 mL e) 179 mL

9. When solid potassium chlorate ($KClO_3$) is heated, the products are potassium chloride and oxygen gas (potassium chloride is stable at the temperature at which this reaction is carried out). A 15.00 g sample of a mixture of potassium chlorate and potassium chloride is heated to completion and 3.14 L of pure oxygen gas is collected at 1.00 atm and 25°C. Determine the mass of potassium chloride present when the reaction is complete.

a) 4.51 g b) 5.67 g c) 6.38 g d) 9.57 g e) 10.9 g

10. Consider two samples of gas: hydrogen gas in a container fitted with a massless, frictionless piston, and helium gas in a rigid, steel container. Initially, both gases are at the same conditions of pressure and temperature. If you double the temperature (measured in Kelvin) of both samples, what is the ratio of the densities of **hydrogen gas to helium gas**?

a) 1:1 b) 1:4 c) 4:1 d) 2:1 e) 1:2

11. Consider a gas mixture consisting of **equal masses** of oxygen gas and a "mystery" gas. At 1.00 atm and 25.0 °C the density of this gas mixture is 1.45 g/L. Determine the identity of the mystery gas.

a) He b) Ne c) Ar d) Kr e) Xe

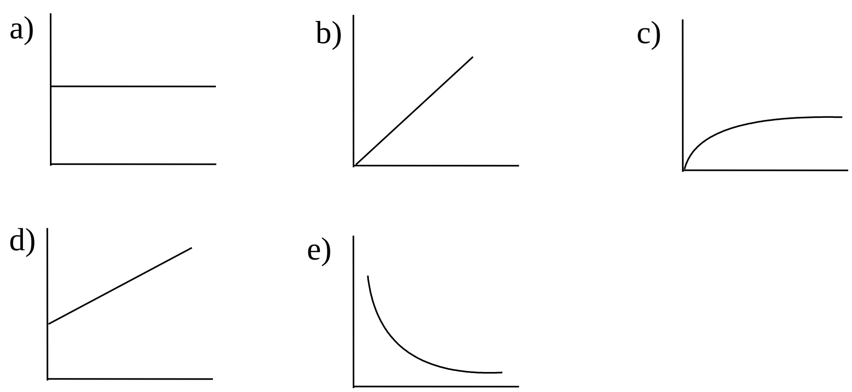
12. Consider three cases of a sample of an ideal, monatomic gas:

Case I: The gas sample is in a sealed, rigid container.
Case II: The gas sample is in a container fitted with a massless, frictionless piston.
Case III: The gas sample is in a rigid container with a pinhole in the side. The container is placed in an environment of air that is initially the same pressure as the gas.

Which of the following best describes how the mean free path (λ) is affected when the temperature of the gas is increased in each of the cases?

a) There is no effect on the mean free path in any of the cases when the temperature is increased.
b) The mean free path increases in two of the cases but remains unaffected in one of the cases when the temperature is increased.
c) The mean free path increases in all three of the when the temperature is increased.
d) The mean free path increases in one case, decreases in one case, and remains unaffected in one case when the temperature is increased.
e) The mean free path increases in one case and decreases in the other two cases when the temperature is increased.

13-15. Indicate which of the graphs below best represents each plot described in questions 13, 14, and 15. Note: the graphs may be used once, more than once, or not at all.



13. densities of helium samples (y) vs. T(K) (x) all at the same pressure. e

14. densities of 1.00 mole helium samples (y) vs. T(K) (x) all with the same volume. a

15. densities of helium samples (y) vs. T(K) (x) all at the same pressure and with the same volume. e

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16. When 2.00*M* of H_2 and 2.00*M* of Cl_2 gases are mixed in a rigid steel container at constant temperature and allowed to come to equilibrium (the reaction is $H_2(g) + Cl_2(g) \rightleftharpoons 2HCl(g)$), the equilibrium concentration of HCl(g) is 1.00*M*. Suppose we start with 1.00*M* HCl(*g*) (no initial $H_2(g)$ or $Cl_2(g)$) and allow it to reach equilibrium (same reaction) at this same temperature. Determine the equilibrium concentration of HCl(*g*).

a) 0.250*M* b) 0.333*M* c) 0.375*M* d) 0.500*M* e) 0.750*M*

17. For the reaction $H_2(g) + F_2(g) \rightleftharpoons 2HF(g)$ at a given temperature, and in a 1.00-L rigid container, the equilibrium concentrations are found to be $[H_2] = 0.050M$, $[F_2] = 0.010M$, $[HF] = 0.40M$. If 0.040 mol of $F_2(g)$ is added to the container at equilibrium, determine the equilibrium concentration of HF(g) once equilibrium is reestablished.

a) 0.35*M* b) 0.40*M* c) 0.42*M* d) 0.45*M* e) 0.50*M*

18. For how many of the following will the equilibrium be **shifted to the left** if the equilibrium system is in a container fitted with a frictionless, massless piston and an inert gas (such as He) is added?

- $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$
- $2H_2(g) + O_2(g) \rightleftharpoons 2H_2O(g)$
- $CO_2(g) + H_2(g) \rightleftharpoons CO(g) + H_2O(l)$
- $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$

a) 0 b) 1 c) 2 d) 3 e) 4

19, 20. Consider the following equilibrium system: $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$ in a rigid, steel container. Initially, the pressures of $SO_2(g)$ and $O_2(g)$ are both equal at 2.000 atm, and the reaction is initiated and allowed to come to equilibrium.

19. At a certain temperature, $K_p = 3.014 \times 10^{-28}$. Determine the partial pressure of **$SO_3(g)$** when the system reaches equilibrium.

a) 8.680×10^{-15} atm
b) 1.736×10^{-14} atm
c) 2.455×10^{-14} atm
d) 4.910×10^{-14} atm
e) 1.389×10^{-13} atm

20. Suppose the reaction is carried out at a temperature in which $K_p = 3.014 \times 10^{28}$. Determine the partial pressure of **$SO_2(g)$** when the system reaches equilibrium.

a) 5.760×10^{-15} atm
b) 8.146×10^{-15} atm
c) 1.152×10^{-14} atm
d) 2.304×10^{-14} atm
e) 2.024×10^{-10} atm

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

a. A solid metallic oxide reacts with hydrogen gas to convert all of the metal to its elemental form as the only solid product. Consider a mixture of copper(I) oxide and copper(II) oxide reacted with an excess of hydrogen gas producing, as one of the products, copper metal. It is noted that there is a 13.14% loss of mass between the solid reactant mixture and the solid product. **Determine the mass percent of each of the oxides** in the original mixture. **Explain why** your **relative answers make sense**. **[10 points]**

Mixture = **78.07% Cu_2O, 21.93% CuO**

21. b. Consider mixing **equal volumes** of aqueous solutions of calcium nitrate and sodium phosphate to produce a solid. After the reaction is complete, there are **three types of distinct ions** in solution and the relative ratio of their concentrations is **1:6:9**. Answer the following:

- **Determine which ion is not in solution** after the reaction is complete.
- **Match** the **ions with their relative concentrations**.
- **Determine the ratio of the initial concentrations** of the two reactant solutions.

Show and explain all work. **Support your answers** to the questions above. **[10 points]**

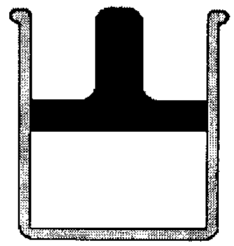
- **Calcium is not in the solution** after the reaction is complete

- So, the **1:6:9 = phosphate: nitrate: sodium**

- We did these calculations with moles, and because the moles of the reactants are equal, and the volumes are equal, the **concentrations of the original solutions are the same (1:1)**.

22. Full credit is reserved for **showing all work** and **providing complete explanations** with a **correct and coherent systematic, 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**.

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



a. To this container you add a saturated hydrocarbon (a gas with the general formula C_xH_{2x+2}) and the stoichiometric amount of oxygen gas (so there are **no leftover reactants**). Hydrocarbons at this temperature react with oxygen gas to produce carbon dioxide and water vapor.

The reaction is initiated and, when complete, allowed to return to the original temperature. The final density has changed by 20.00% compared with the initial density of the reactant mixture. **Does the density increase or decrease**? **Explain**. **Determine the chemical formula** of the hydrocarbon. **Show all work** and **explain**. **Is this an empirical or molecular** formula? **Justify** your answer. Please use the next page if needed. **[14 points]**

- The molecular formula for the hydrocarbon is **C_7H_{16}**.

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

22. b. Consider that an **excess of oxygen** gas is added with this particular hydrocarbon (that you determined in part “a”) and that the final density changes by 18.75%.

Determine the initial mole ratio of [oxygen gas: hydrocarbon] in such a case. **Show all work** and **explain**.

If you cannot solve part “a,” **explain and show** how you would solve this problem if you knew the formula of the hydrocarbon. **[6 points]**

- Ratio = 12:1

23. 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**.

Ammonia gas (NH_3) can decompose to form nitrogen and hydrogen gases. Consider ammonia gas placed in a rigid, closed container that reaches equilibrium according to the following equation:

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

The reaction occurs at constant temperature, and, at this temperature, the equilibrium constant, K_p, for the reaction as written above is equal to 0.314. It is noted that the pressure changes by 20.00% when the pressure of the **original pure ammonia** is compared to the pressure of the **equilibrium mixture**.

a. **Determine the initial pressure of ammonia** in the container. **Show and explain all work**. **[10 points]**

Please use the next page if needed.

- Initial pressure of NH_3 = x = **8.627 atm**.

23. a. Continue work on this problem below, if needed.

23. b. Suppose the rigid container was actually fitted with a massless frictionless piston that was locked in place and is now unlocked. If the outside pressure is 1.00 atm, **determine the range for the equilibrium pressure** for ammonia when the piston has stopped moving. That is, your answer should be: "The equilibrium pressure for ammonia is less than ____", or, "the equilibrium pressure for ammonia is greater than ____". You do **not** need to solve for the equilibrium pressure (although you can if you wish to). **Show and explain all work**. **[10 points]**

- **The equilibrium pressure of ammonia will be less than 0.6663 atm.**