

Please follow the instructions for each section of the exam. Show your work on all mathematical problems. Provide answers with the correct units and significant figures. Be concise in your answers to discussion questions.

Part 0: Warmup. 4 points each

1. For a fixed amount of gas at a fixed pressure, changing the temperature from 100°C to 200K causes the gas volume to:

- a. double
- b. increase
- c. decrease
- d. stay the same

Answer _____ **C** _____

2. Under what conditions is Cl₂ most likely to behave like an ideal gas?

- a. 100°C and 10.0 atm
- b. 0°C and 0.50 atm
- c. 200°C and 0.50 atm
- d. 400°C and 10.0 atm

Answer _____ **C** _____

3. To precipitate Zn²⁺ from a solution of Zn(NO₃)₂, add

- a. NH₄Cl
- b. MgBr₂
- c. K₂CO₃
- d. (NH₄)₂SO₄

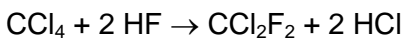
Answer _____ **C** _____

4. In the half reaction in which NpO₂⁺ is converted to Np⁴⁺, the number of electrons appearing in the half reaction is

- a. 1
- b. 2
- c. 3
- d. 4

Answer _____ **A** _____

5. In the reaction of 2 mol CCl₄ with an excess of HF, 1.70 mol CCl₂F₂ is obtained.



- a. The theoretical yield is 1.70 mol CCl₂F₂.
- b. The theoretical yield is 1.00 mol CCl₂F₂.
- c. The theoretical yield depends on how large an excess of HF was used.
- d. The percent yield is 85%.

Answer _____ **D** _____

Part I: Complete all of problems 6-10

6. Complete the chart below: (12 points)

Species	Name	Oxidation States			Water Soluble? (Y/N)
$\text{Ca}(\text{ClO}_4)_2$	calcium perchlorate	Ca = +2	Cl = +7	O = -2	Y
$\text{Zn}_3(\text{PO}_4)_2$	zinc (II) phosphate	Zn = +2	O = -2	P = +5	N

7. Ammonia can be generated by heating together the solids NH_4Cl and $\text{Ca}(\text{OH})_2$ to produce NH_3 , water, and CaCl_2 . If a mixture containing 33.0 g each of ammonium chloride and calcium hydroxide is heated, how many grams of ammonia will form? (10 points)



$$33.0 \text{ g } \text{NH}_4\text{Cl} \times \frac{1 \text{ mol } \text{NH}_4\text{Cl}}{53.4912 \text{ g}} \times \frac{2 \text{ mol } \text{NH}_3}{2 \text{ mol } \text{NH}_4\text{Cl}} \times \frac{17.0356 \text{ g } \text{NH}_3}{1 \text{ mol } \text{NH}_3} = 10.51 \text{ g } \text{NH}_3$$

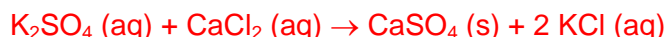
$$33.0 \text{ g } \text{Ca}(\text{OH})_2 \times \frac{1 \text{ mol } \text{Ca}(\text{OH})_2}{74.093 \text{ g}} \times \frac{2 \text{ mol } \text{NH}_3}{1 \text{ mol } \text{Ca}(\text{OH})_2} \times \frac{17.0356 \text{ g } \text{NH}_3}{1 \text{ mol } \text{NH}_3} = 15.17 \text{ g } \text{NH}_3$$

Since the ammonium chloride produces less, it must be the limiting reagent, so 10.5 g NH_3 will be formed.

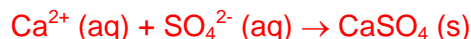
8. Write the (1) *overall reaction* and (2) *net ionic equation* for the following reactions. Indicate the state of all reactants and products. (10 points)

a. Aqueous potassium sulfate with aqueous calcium chloride.

(1) Overall reaction:



(2) Net ionic equation:

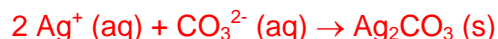


b. Aqueous sodium carbonate with aqueous silver nitrate.

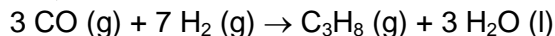
(1) Overall reaction:



(2) Net ionic equation:



9. Calculate the volume of hydrogen gas, measured at 26°C and 751 torr required to react with 28.5 L of carbon monoxide, measured at 0°C and 760 torr in the reaction below. (10 points)



$$n_{\text{CO}} = \frac{PV}{RT} = \frac{(1 \text{ atm})(28.5 \text{ L})}{(0.08206 \text{ L atm/mol K})(273 \text{ K})} = 1.272 \text{ mol CO}$$

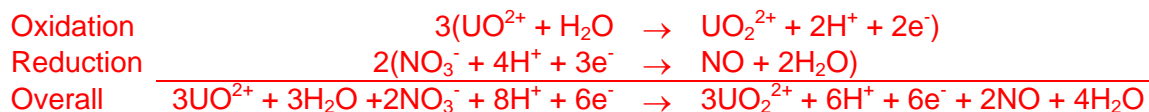
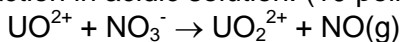
$$1.272 \text{ mol CO} \times \frac{7 \text{ mol H}_2}{3 \text{ mol CO}} = 2.969 \text{ mol H}_2$$

$$P_{\text{H}_2} = 751 \text{ torr} \times \frac{1 \text{ atm}}{760 \text{ torr}} = 0.9882 \text{ atm}$$

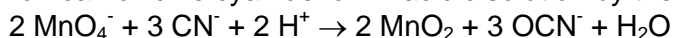
$$V = \frac{nRT}{p} = \frac{(2.969 \text{ mol})(0.08206 \text{ L atm/mol K})(299 \text{ K})}{(0.9882 \text{ atm})} = 73.7 \text{ L} = \mathbf{74 \text{ L}}$$

10. Redox reactions:

- a. Balance the following reaction in acidic solution. (10 points)



- b. Permanganate ion can oxidize cyanide ion in acidic solution by the reaction below.



Write the corresponding balanced reaction that would occur in basic solution. (2 points)



Since $\text{H}^+ + \text{OH}^- = \text{H}_2\text{O}$:

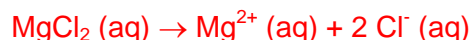


After cancelling waters:



Part II. Answer two (2) of problems 11-14. Clearly mark the problem you do not want graded. 12 points each.

11. You are following a laboratory procedure to prepare a dilute chloride solution to use as a standard in an absorbance measurement. You prepare the standard by dissolving 1.45 g MgCl_2 in 100.0 mL of solution, which you label solution A. After mixing, you pipet 3.00 mL of solution A to a 50.0 mL volumetric flask, and dilute to the mark to prepare solution B. Finally, you pipet 2.00 mL of solution B into a 25 mL volumetric flask and dilute to the mark to prepare solution C. What is the molarity of *chloride ions* in solution C? Assume MgCl_2 is a strong electrolyte.



$$1.45 \text{ g } \text{MgCl}_2 \times \frac{1 \text{ mol } \text{MgCl}_2}{94.2104 \text{ g}} \times \frac{2 \text{ mol } \text{Cl}^-}{1 \text{ mol } \text{MgCl}_2} \times \frac{1}{0.100 \text{ L}} = \frac{0.3078 \text{ mol } \text{Cl}^-}{\text{L}} = [\text{A}]$$

$$M_1 V_1 = M_2 V_2$$

For solution B:

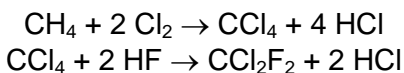
$$M_B = \frac{M_A V_A}{V_B} = \frac{(0.3078 \text{ M})(3.00 \text{ mL})}{50.00 \text{ mL}} = 0.01847 \text{ M} = [\text{B}]$$

For solution C:

$$M_C = \frac{M_B V_B}{V_C} = \frac{(0.01847 \text{ M})(2.00 \text{ mL})}{25.00 \text{ mL}} = 0.001478 \text{ M} = [\text{C}]$$

So, the molarity of chloride ions in solution C is **0.001478 M**

12. Dichlorodifluoromethane, once widely used as a refrigerant, can be prepared by the balanced reactions shown. How many moles of Cl_2 must be consumed to produce 2.25 kg CCl_2F_2 ? What volume would this Cl_2 gas occupy at STP? Assume all the CCl_4 produced in the first reaction is consumed in the second.



How many moles of Cl_2 gas is needed?

$$2.25 \text{ kg } \text{CCl}_2\text{F}_2 \times \frac{1 \text{ mol } \text{CCl}_2\text{F}_2}{120.913 \text{ g}} \times \frac{10^3 \text{ g}}{1 \text{ kg}} \times \frac{1 \text{ mol } \text{CCl}_4}{1 \text{ mol } \text{CCl}_2\text{F}_2} \times \frac{2 \text{ mol } \text{Cl}_2}{1 \text{ mol } \text{CCl}_4} = 37.22 \text{ mol } \text{Cl}_2$$

What volume will this gas occupy at STP?

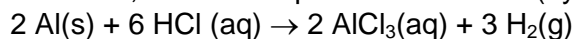
$$V = \frac{nRT}{p} = \frac{(37.22 \text{ mol})(0.08206 \text{ L atm/mol K})(273 \text{ K})}{(1 \text{ atm})} = 833.7 \text{ L} = \mathbf{834 \text{ L}}$$

13. A NaOH solution cannot be made up to an exact concentration simply by weighing out the required mass of solid NaOH, because the NaOH is not pure. Also, water vapor condenses on the solid as it is weighed. To determine the concentration of such solutions, they must be standardized by titration. For this purpose, a 25.00 mL sample of NaOH solution requires 33.61 mL of 0.1086 M HCl. What is the molarity of the NaOH? Include a balanced reaction in your solution.



$$33.61 \text{ mL HCl} \times \frac{0.1086 \text{ mol HCl}}{1 \text{ L HCl}} \times \frac{1 \text{ mol NaOH}}{1 \text{ mol HCl}} \times \frac{1}{25.00 \text{ mL}} = \mathbf{0.146 \text{ M NaOH}}$$

14. A 2.89 g aluminum ore sample is reacted with excess HCl in the reaction below, and the liberated H_2 is collected over water at 25°C at a barometric pressure of 744 mm Hg. If 322 mL of hydrogen is collected, what is the percent aluminum (by mass) in the ore sample?



$$P_T = P_{\text{H}_2} + P_{\text{H}_2\text{O}} \text{ so that } 744 \text{ mm Hg} = P_{\text{H}_2} + 23.76 \text{ mm Hg and } P_{\text{H}_2} = 720.24 \text{ mm Hg}$$

$$P_{\text{H}_2} = 720.24 \text{ mm Hg} \times \frac{1 \text{ atm}}{760 \text{ mm Hg}} = 0.9476 \text{ atm}$$

$$n_{\text{H}_2} = \frac{PV}{RT} = \frac{(0.9476 \text{ atm})(0.322 \text{ L})}{(0.08206 \text{ L}\cdot\text{atm/mol}\cdot\text{K})(298\text{K})} = 0.01248 \text{ mol H}_2$$

$$0.01248 \text{ mol H}_2 \times \frac{2 \text{ mol Al}}{3 \text{ mol H}_2} \times \frac{26.9815 \text{ g Al}}{1 \text{ mol Al}} = 0.2245 \text{ g Al}$$

$$\frac{0.2245 \text{ g Al}}{2.89 \text{ g sample}} \times 100\% = \mathbf{7.77\% \text{ Aluminum}}$$

Possibly Useful Information

$R = 0.08206 \text{ L atm mol}^{-1} \text{ K}^{-1}$	STP = 1 atm, 0°C
1 atmosphere = 760 Torr	$\left(P + a\left(\frac{n}{V}\right)^2\right)(V - bn) = nRT$
$P_{\text{total}} = n_{\text{total}}RT/V$	$P_A = X_a P_{\text{total}}$
$N_a = 6.02214 \times 10^{23} \text{ mol}^{-1}$	$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$

Molar Masses	
Compound	Molar Mass (g/mol)
AlCl ₃	133.3396
C ₃ H ₈	44.097
Ca(OH) ₂	74.093
CaCl ₂	110.983
CCl ₂ F ₂	120.913
CCl ₄	153.822
CH ₄	16.043
Cl ₂	70.9504
CO	28.010
H ₂	2.01588
H ₂ O	18.0153
HCl	36.4606
HF	20.00634
MgCl ₂	94.2104
NaOH	39.9971
NH ₃	17.0356
NH ₄ Cl	53.4912

Vapor Pressure of Water at Various Temperatures

Temperature (°C)	Vapor Pressure (mmHg)
15.0	12.79
17.0	14.53
19.0	16.48
21.0	18.65
23.0	21.07
25.0	23.76
30.0	31.82
50.0	92.51

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TABLE 5.1 Solubility Guidelines for Common Ionic Solids

Follow the lower-numbered guideline when two guidelines are in conflict. This leads to the correct prediction in most cases.

1. Salts of group 1 cations (with some exceptions for Li⁺) and the NH₄⁺ cation are soluble.
2. Nitrates, acetates, and perchlorates are soluble.
3. Salts of silver, lead, and mercury(I) are insoluble.
4. Chlorides, bromides, and iodides are soluble.
5. Carbonates, phosphates, sulfides, oxides, and hydroxides are insoluble (sulfides of group 2 cations and hydroxides of Ca²⁺, Sr²⁺, and Ba²⁺ are slightly soluble).
6. Sulfates are soluble except for those of calcium, strontium, and barium.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1A	2A	3B	4B	5B	6B	7B	8	9B	10	1B	2B	3A	4A	5A	6A	7A	8A
1 H 1.00794	2 He 4.00260	3 Li 6.941	4 Be 9.01218	5 B 10.811	6 C 12.011	7 N 14.0067	8 O 15.9994	9 F 18.9984	10 Ne 20.1797	11 Na 22.9898	12 Mg 24.3050	13 Al 26.9815	14 Si 28.0855	15 P 30.9738	16 S 32.066	17 Cl 35.4527	18 Ar 39.948
19 K 39.0983	20 Ca 40.078	21 Sc 44.9559	22 Ti 47.88	23 V 50.9415	24 Cr 51.9961	25 Mn 54.9381	26 Fe 55.847	27 Co 58.9332	28 Ni 58.693	29 Cu 63.546	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.9216	34 Se 78.96	35 Br 79.904	36 Kr 83.80
37 Rb 85.4678	38 Sr 87.62	39 Y 88.9059	40 Zr 91.224	41 Nb 92.9064	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.906	46 Pd 106.42	47 Ag 107.868	48 Cd 112.411	49 In 114.818	50 Sn 118.710	51 Sb 121.757	52 Te 127.60	53 I 126.904	54 Xe 131.29
55 Cs 132.905	56 Ba 137.327	57 *La 138.906	72 Hf 178.49	73 Ta 180.948	74 W 183.84	75 Re 186.207	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.967	80 Hg 200.59	81 Tl 204.383	82 Pb 207.2	83 Bi 208.980	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra 226.025	89 †Ac 227.028	104 Rf (261)	105 Db (262)	106 Sg (266)	107 Bh (264)	108 Hs (277)	109 Mt (268)	110 Ds (271)	111 Rg (272)							

*Lanthanide series	58 Ce 140.115	59 Pr 140.908	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.965	64 Gd 157.25	65 Tb 158.925	66 Dy 162.50	67 Ho 164.930	68 Er 167.26	69 Tm 168.934	70 Yb 173.04	71 Lu 174.967
†Actinide series	90 Th 232.038	91 Pa 231.036	92 U 238.029	93 Np 237.048	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)