

This exam is scheduled for 75 minutes and I anticipate it to take the full time allotted. You are free to leave if you finish. In multiple part problems, points awarded will not be penalized for incorrect answer on previous parts, so simply **move on if you get stuck on one part**. If you need to, make up an answer for the previous part. Always neatly show work for partial credit.

Equations and constants:

$$\begin{aligned} E &= h\nu & c &= 2.998 \times 10^8 \text{ m/s} & c &= \lambda\nu & h &= 6.626 \times 10^{-34} \text{ J} \\ E_n &= \frac{-2.18 \times 10^{-18} \text{ J}}{n^2} & KE &= \frac{1}{2} m v^2 & E_{\text{coulomb}} &= 231 \text{ pm} \cdot a \text{ J} \frac{q_1 q_2}{r} \\ m_{\text{electron}} &= 9.109 \times 10^{-31} \text{ kg} & \lambda &= \frac{h}{mv} & V_{\text{cylinder}} &= \pi r^2 h \end{aligned}$$

$$PV = nRT \quad R = 0.08206 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}}$$

$$P = \frac{F}{\text{area}} \quad F = ma$$

$$1 \text{ atm} = 760 \text{ mmHg} = 760 \text{ torr} \quad 1 \text{ atm} = 1.01325 \text{ bar} \quad 1 \text{ atm} = 101325 \text{ Pa}$$

1. How many oxygen atoms are found in 14.25 grams of sodium carbonate?

$$14.25 \text{ g Na}_2\text{CO}_3 \left| \frac{\text{mol}}{105.99 \text{ g}} \right| \frac{3 \text{ mol O}}{1 \text{ mol Na}_2\text{CO}_3} \left| \frac{6.022 \times 10^{23} \text{ atoms}}{1 \text{ mol}} \right| = 2.429 \times 10^{23} \text{ atoms}$$

Na_2CO_3
105.99 g

2. Determine $[\text{NO}_3^-]$ when 36.224 g of magnesium nitrate is dissolved in 1.86 L of water.

$$36.244 \text{ g Mg(NO}_3)_2 \left| \frac{\text{mol}}{148.33 \text{ g}} \right| \frac{2 \text{ mol NO}_3^-}{1 \text{ mol Mg(NO}_3)_2} = \frac{0.489 \text{ mol NO}_3^-}{1.86 \text{ L}} = 0.262 \text{ M}$$

$\text{Mg(NO}_3)_2 = 148.33 \text{ g/mol}$

3. What is the mass of oxygen found in 244.5 mL of dinitrogen oxide gas at 3.64 atm and 145 °C

$$n = \frac{PV}{RT} = \frac{(3.64 \text{ atm})(0.2445 \text{ L})}{(0.08206 \frac{\text{L}\cdot\text{atm}}{\text{mol}\cdot\text{K}})(145 + 273.15)} = 0.0259 \text{ mol N}_2\text{O} \left| \frac{1 \text{ mol O}}{1 \text{ mol N}_2\text{O}} \right| = 0.0259 \text{ mol}$$

$$0.0259 \text{ mol O} \left| \frac{16 \text{ g}}{\text{mol}} \right| = 0.4144 \text{ g}$$

4. Determine the empirical formula of a compound that is 3.26% hydrogen, 19.36% carbon, and 77.38% oxygen.

$$\frac{3.26 \text{ g H}}{1.01 \text{ g}} = 3.23 \div 1.62 = 2$$

$$\frac{19.36 \text{ g C}}{12.01 \text{ g}} = 1.62 \div 1.62 = 1$$

$$\frac{77.38 \text{ g O}}{16 \text{ g}} = 4.84 \div 1.62 = 3$$



5. Barium sulfate can be made when aluminum sulfate is mixed together with barium nitrate.

a. Write a balanced reaction.



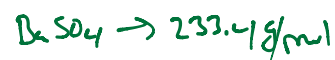
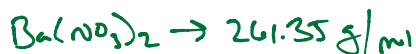
b. What type of reaction is described here?

double displacement

c. Write a net ionic equation for this reaction.



d. If 5.000 grams of each reactant are combined, determine the mass of barium sulfate that will be made if the reaction proceeds with a 90% yield.



$$5 \text{ g Al}_2(\text{SO}_4)_3 \left| \frac{\text{mol}}{342.17 \text{ g}} \right| \left| \frac{3 \text{ mol BaSO}_4}{1 \text{ mol}} \right| \left| \frac{233.4 \text{ g}}{\text{mol}} \right| = 10.23 \text{ g}$$

$$5 \text{ g Ba}(\text{NO}_3)_2 \left| \frac{\text{mol}}{261.35 \text{ g}} \right| \left| \frac{3 \text{ mol}}{3 \text{ mol}} \right| \left| \frac{233.4 \text{ g}}{\text{mol}} \right| = 4.465 \text{ g BaSO}_4 \times 0.9 = \boxed{4.019 \text{ g}}$$

6. Write a balanced reaction for the combustion of solid $\text{C}_{15}\text{H}_{33}$.



7. 172 mL of water is added to a flask containing 300 mL of 655 mM NaCl. What is the new concentration of the solute?

$$\frac{300 \text{ mL} \left| \frac{10^{-3} \text{ L}}{1 \text{ mL}} \right| 655 \frac{\text{mmol}}{\text{L}}}{0.3 + 0.172 \text{ L}} = \frac{196.5 \text{ mmol}}{0.472 \text{ L}} = 416.3 \text{ mM}$$

8. A flask contains 3.2 moles of an ideal gas at 120 °C. If another 4.4 moles of the gas is added to the flask without changing the volume or pressure, determine the new temperature.

variables $n \uparrow T$

$$PV = nRT$$

$$\frac{PV}{R} = nT$$

$$n_1 T_1 = n_2 T_2$$

$$3.2 (120 + 273.15) = (3.2 + 4.4) T_2$$

$$T_2 = 165.54 \text{ K}$$

$$T_2 = -107.6 \text{ } ^\circ\text{C}$$

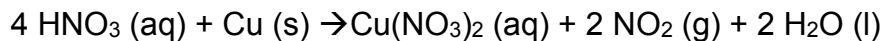
9. For each pair, identify which compound will be more soluble in C_8H_{18} . **Clearly justify your answer.**

a. H_2O or H_2S non-polar

b. NCl_3 or PCl_3 non-polar

c. NaCO_3 or SO_3
 ↑ ionic ↑ polar ← more likely to dissolve in non-polar solvent

10. Consider the following reaction:



58.6 mL of 4.12 M HNO_3 is added to a flask containing 3604 mg of solid copper. If the reaction occurs in a 4.00 L flask held at 100°C , determine each of the following:

- a. The total pressure in the after the reaction completes. 0.868 atm
- b. The concentration of $\text{Cu}(\text{NO}_3)_2$ that is produced. 968 mM.
- c. The mass of $\text{Cu} (\text{s})$ remaining. 0 mg
- d. The concentration of HNO_3 remaining. 249 mM

$$\frac{0.0586 \text{ L} \mid 4.12 \text{ mol HNO}_3}{\text{L}} \mid \frac{2 \text{ NO}_2}{4 \text{ HNO}_3} = 0.1207 \text{ mol NO}_2$$

$$\frac{3.604 \text{ g Cu} \mid \text{mol}}{63.55 \text{ g}} \mid \frac{2 \text{ HNO}_3}{1 \text{ Cu}} = 0.1134 \text{ mol NO}_2$$

$$P = \frac{nRT}{V} = \frac{0.1134 (0.08206) (373.15)}{4}$$

$$\frac{0.1134 \text{ mol NO}_2 \mid 1 \text{ Cu}(\text{NO}_3)_2}{2 \text{ NO}_2} = \frac{0.0567 \text{ mol Cu}(\text{NO}_3)_2}{0.0586 \text{ L}} = 0.968 \text{ M}$$

$$\frac{0.1134 \text{ mol NO}_2 \mid 4 \text{ HNO}_3}{2 \text{ NO}_2} = 0.2268 \text{ mol used}$$

$$\frac{0.0586 \text{ L} \mid 4.12 \text{ mol}}{\text{L}} = 0.2414 \text{ mol @ start}$$

$$0.2414 - 0.2268 = \frac{0.0146 \text{ mol}}{0.0586 \text{ L}} \\ [\text{HNO}_3] = 0.249 \text{ M}$$

11. Consider the combustion of an unknown compound ($C_xH_yN_z$). Exactly 30 grams of this compound is combusted in a 1.5 L flask at a constant temperature of 300 K. After the combustion reaction completes, 8.327 atm of CO_2 , 12.490 atm of H_2O , and 2.776 atm of NO_2 is produced.

a. What is the empirical formula of this compound?

$$CO_2 \quad n = \frac{(8.327)(1.5)}{(0.08206)(300)} = 0.507 \text{ mol } CO_2 \quad \left| \begin{array}{l} 1 \text{ mol C} \\ 1 \text{ mol } CO_2 \end{array} \right. = 0.507 \text{ mol C} \div 0.169 = 3$$

$$H_2O \quad n = \frac{(12.490)(1.5)}{(0.08206)(300)} = 0.761 \text{ mol } H_2O \quad \left| \begin{array}{l} 2 \text{ H} \\ 1 \text{ } H_2O \end{array} \right. = 1.522 \text{ mol H} \div 0.169 = 9$$

$$NO_2 \quad n = \frac{(2.776)(1.5)}{(0.08206)(300)} = 0.169 \text{ mol } NO_2 \quad \left| \begin{array}{l} 1 \text{ N} \\ 1 \text{ } NO_2 \end{array} \right. = 0.169 \text{ mol N} \div 0.169 = 1$$

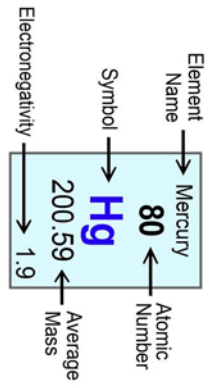


b. Analysis shows that the molecular weight of this compound is 532.5 g mol^{-1} . What is the molecular formula?

$$C_3H_9N = 59.13 \text{ g/mol} \quad \frac{532.5}{59.13} = 9$$



Periodic Table of the Elements



1 Hydrogen H 1.01	2 Helium He 4.00																																		
3 Lithium Li 6.94	4 Beryllium Be 9.01	5 Boron B 10.81	6 Carbon C 12.01	7 Nitrogen N 14.01	8 Oxygen O 16.00	9 Fluorine F 19.00	10 Neon Ne 20.18																												
11 Sodium Na 22.99	12 Magnesium Mg 24.31	13 Aluminum Al 26.98	14 Silicon Si 28.09	15 Phosphorus P 30.97	16 Sulfur S 32.07	17 Chlorine Cl 35.45	18 Argon Ar 39.95																												
19 Potassium K 39.10	20 Calcium Ca 40.08	21 Scandium Sc 44.96	22 Titanium Ti 47.88	23 Vanadium V 50.94	24 Chromium Cr 52.00	25 Manganese Mn 54.94	26 Iron Fe 55.85	27 Cobalt Co 58.93	28 Nickel Ni 58.69	29 Copper Cu 63.55	30 Zinc Zn 65.39	31 Gallium Ga 69.72	32 Germanium Ge 72.61	33 Arsenic As 74.92	34 Selenium Se 78.96	35 Bromine Br 79.90	36 Krypton Kr 83.80																		
37 Rubidium Rb 85.47	38 Strontium Sr 87.62	39 Yttrium Y 88.91	40 Zirconium Zr 91.22	41 Niobium Nb 92.91	42 Molybdenum Mo 95.94	43 Technetium Tc (98)	44 Ruthenium Ru 101.07	45 Rhodium Rh 102.91	46 Palladium Pd 106.42	47 Silver Ag 107.87	48 Cadmium Cd 112.41	49 Indium In 114.82	50 Tin Sn 118.71	51 Antimony Sb 121.76	52 Tellurium Te 127.60	53 Iodine I 126.90	54 Xenon Xe 131.29																		
55 Cesium Cs 132.91	56 Barium Ba 137.33	57 Lanthanum La 138.91	58 Cerium Ce 140.12	59 Praseodymium Pr 140.91	60 Neodymium Nd 144.24	61 Promethium Pm (145)	62 Samarium Sm 150.36	63 Europium Eu 151.97	64 Gadolinium Gd 157.25	65 Terbium Tb 158.93	66 Dysprosium Dy 162.50	67 Holmium Ho 164.93	68 Erbium Er 167.26	69 Thulium Tm 168.93	70 Ytterbium Yb 173.04	71 Lutetium Lu 174.97	72 Hafnium Hf 178.49	73 Tantalum Ta 180.95	74 Tungsten W 183.84	75 Rhenium Re 186.21	76 Osmium Os 190.23	77 Iridium Ir 192.22	78 Platinum Pt 195.08	79 Gold Au 196.97	80 Mercury Hg 200.59	81 Thallium Tl 204.38	82 Lead Pb 207.20	83 Bismuth Bi 208.98	84 Polonium Po (209)	85 Astatine At (210)	86 Radon Rn (222)				
87 Francium Fr (223)	88 Radium Ra (226)	89-102 Lanthanides	103 Lr (262)	104 Rf (261)	105 Db (262)	106 Sg (266)	107 Bh (264)	108 Hs (269)	109 Mt (268)	110 Ds (271)	111 Rg (272)	112 Cn (277)	113 Nh (284)	114 Fl (289)	115 Uup (288)	116 Lv (293)	117 Uus (294)	118 Uuo (294)																	
		**actinides																																	

Insoluble Compounds

Compounds Containing	Notable Exceptions
Carbonate	Group IA and NH ₄ ⁺
Phosphate	Group IA and NH ₄ ⁺
Sulfide	Group IA, IIA, and NH ₄ ⁺
Hydroxide	Group IA, NH ₄ ⁺ , Ca ²⁺ , Sr ²⁺ , Ba ²⁺

Soluble Compounds

Compounds	Notable Exceptions:
Group 1A ions	None
Ammonium	None
Acetate	None
Nitrate	None
Halides	Ag ⁺ , Pb ²⁺ , Hg ₂ ²⁺
Sulfate	Ca ²⁺ , Sr ²⁺ , Ba ²⁺ , Pb ²⁺