NAME (print) _____
(last) (first)

Some Physical Constants

Specific Heats of water:	gas, 2.02	liquid, 4.18	solid, 2.03 Joules / g-deg
Not identified:	6.626 E – 34 $J \cdot \sec$		3.00 E + 8 $meters / \sec$
Enthalpies for water:	vaporization, 40.7 kJ / mole		fusion, 6000 J / mole
Gas constant	0.082 $\frac{L-atm}{K-mole}$		8.31 $\frac{J}{K-mole}$

1. A molecular compound is composed of four elements. Analysis for three of them gives the following results: 34.45 % zirconium (at.no. 40), 40.05 % chlorine, and 2.28 % hydrogen. (The fourth element could not be analyzed with available equipment.) A separate test shows that the molecule probably contains six chlorine atoms.

a. How many zirconium atoms are present in one molecule?

Six chlorine atoms constitute 40.05 % of the standard mass of the compound.

Six chlorine have a standard mass of 6 x 35.45 = 212.7 grams.
So, 212.7 grams are 40.05 % of the standard mass of the compound.

So, standard mass compound = 212.7 / 0.4005 = 531 grams per mole

Zirconium accounts for 34.45 % of the standard mass of the compound, or
0.3445 x 531 = 182.9 grams

Each zirconium atom has a standard mass of 91.2 grams.

Conclusion: there are TWO zirconium atoms in one molecule of the compound.

b. How many hydrogen atoms are present in one molecule?

Hydrogen accounts for 2.28 % of the standard mass.
Mass of hydrogen in the compound = 531 x 0.0228 = 12 grams
Number of hydrogen atoms in one molecule of the compound is TWELVE.

c. If one atom of the fourth element is present in each molecule, what is the atomic mass of the fourth element?

The first three elements account for: 34.45 + 40.04 + 2.28 = 76.78 % of the std.mass.
The fourth element accounts for 100 – 76.78 = 23.22 %.
Mass of fourth element = 531 x 0.2322 = 123.3 grams/mole (element ???)

d. If four atoms of the fourth element are present in each molecule, what is the atomic mass of the fourth element?

In this case atomic mass = 123.3 / 4 = 30.8 grams/mole (phosphorus)

e. Select the more chemically reasonable choice (i.e., part c, or part d), and write a chemical formula for the compound based on this choice.

Case D is better using Phosphorus. Chemical Formula = $Zr_2Cl_6H_{12}P_4$

2. Two different binary compounds are composed of the same elements. A sample of one compound is analyzed and found to contain 47.71 % of a metal element. A sample of the other compound is similarly analyzed and found to contain 57.78 % of the same metal element. What is the integer ratio of the second element present in both compounds?

ONE compound	OTHER compound
% X = 100 – 47.71 (metal) = 52.29 % X	% X = 100 – 57.78 (metal) = 42.22 % X
Ratio of X / M = 52.29 / 47.71 = 1.096	Ratio of X / M = 42.22 / 57.78 = 0.7307

$$\frac{\frac{X}{M}\,ONE\ compound}{\frac{X}{M}\,OTHER\ compound} = \frac{1.096}{0.7307} = 1.4999 = 1.5 = 3/2$$

For the same amount of metal in both compounds,

there are THREE of the second element in ONE compound,

for every TWO of the second element in the OTHER compound.

3. A small glass container has a mass of 27.6918 grams when clean and dry. Several pieces of a solid specimen are added to the container until the combined mass becomes 51.4243 grams. An organic liquid is added next so as to cover the solid pieces and fill the container; the mass now changes to 57.2398 grams. The density of organic liquid is 0.951 g / mL. In a separate measurement, the container was completely filled with only the liquid, and the recorded mass was 42.0890 grams. What is the density of the solid specimen?

Density of the Solid Specimen is: 2.630 g / cm^3

4. An aqueous solution is prepared by dissolving 8.4732 grams of copper(II) nitrate, $Cu(NO_3)_2$, in enough water to form 500 mL of solution. A second solution labeled as 0.105 M sodium arsenate, Na_3AsO_4, is obtained from the chemistry stockroom.

a. What is the molarity of the copper(II) nitrate solution?

FW copper(II) nitrate = 63.55 + 2(14+48) = 187.55 g/mole

Molarity = $\frac{(8.4732/187.55)moles}{0.500L}$ = 0.09036 molalr

b. Write a net ionic equation representing the solute in the aqueous solution of copper(II) nitrate.

$$Cu(NO_3)_{2\,(aq)} \rightarrow Cu^{2+}_{(aq)} + 2\,NO^{1-}_{3(aq)}$$

c. Write a net ionic equation representing the solute in the aqueous solution of sodium arsenate.

$$Na_3AsO_{4\,(aq)} \rightarrow 3\,Na^{1+}_{(aq)} + AsO^{3-}_{4\,(aq)}$$

d. When 25.00 mL of the copper(II) nitrate solution is mixed with 15.00 mL of the sodium arsenate solution, a copper(II) arsenate precipitate forms - $Cu_3(AsO_4)_2$. Write a net ionic equation representing the precipitation reaction.

$$3\,Cu^{2+}_{(aq)} + 2\,AsO^{3-}_{4(aq)} = Cu_3(AsO_4)_{2\,(solid)}$$

e. Set-up a B4, REACT, AFTR / millimole grid for this reaction and fill-in all cells.

ion/cmpd	$Cu^{2+}_{(aq)}$	$AsO^{3-}_{4(aq)}$	$Cu_3(AsO_4)_2$
B4	25x0.09036 = 2.259 mm	15x0.105 = 1.575 mm	none
REACT 3 : 2 : 1	-2.259 mm	(2/3)x(-2.259) = -1.506	+0.7530
AFTR	none	0.069	0.7530

f. How many grams of precipitate will be formed?
(Formula weight of ppt. = 468.5 g/mole)

0.7530 mm x 468.5 mg/mole = 353 mg = 0.353 grams ppt.

g. What is the concentration (molarity) of the reactant ion present in an excess amount, after the reaction is complete?

Molarity = $\frac{0.06905mmoles}{40mL}$ = 0.00173 molar in arsenate anion

5. Given: $ClO^{1-}_{(aq)} + PH_{3\,(gas)} = Cl_{2\,(gas)} + P_{4\,(solid)}$ *(base)*

a. Construct a balanced half-cell for the oxidation process:

Answer not provided.

b. Construct a balanced half-cell for the reduction process:

c. Construct a balanced chemical equation for the complete reaction:

6. An organic substance is composed of the elements of carbon, hydrogen and sulfur. A mixture of this substance (as a gas) with molecular oxygen gas is prepared so that both reacting gases will be completely used up in a combustion reaction.

When 6.38 Liters of this gaseous mixture is burned it produces 2.552 L of carbon dioxide gas, 1.701 L of sulfur dioxide gas, and 2.552 L of water in the gas state. All volumes were measured at same conditions of temperature and pressure.

a. What volume of molecular oxygen gas was present in the initial 6.38 Liter mixture of gases?

2.552 L CO_2 gas is equivalent to	2.552 L O_2	Total L O_2
1.701 L SO_2 gas " " "	1.701 L O_2	**5.529 Liters**
2.552 L H_2O gas " " "	1.276 L O_2	

b. What is the empirical formula the organic substance?

Volume Compound = 6.38 – 5.529 = 0.851 Liters compound

(Because all gas volumes are measured at same conditions of temperature and pressure, gas volumes are directly related to gas moles (Avogadro's Principle).

0.851 moles of compound yield 2.552 moles CO_2 or 2.552 mole CARBON

1.701 moles SO_2 or 1.701 mole SULFUR

2.552 moles H_2O or 5.104 mole HYDROGEN

Divide through by moles of compound (0.851), to obtain a MOLECULAR formula.

1.0 CMPD 3.0 CARBON 2.0 SULFUR 6.0 HYDROGEN

EMPIRICAL FORMULA (is also the same): **$C_3H_6S_2$**

c. What is the molecular formula of the organic substance?

MOLECULAR FORMULA IS: **$C_3H_6S_2$**

Because the relationship between moles of compound (0.851) and moles of each element present in the compound has been established, (2.552 C, 1.701 S, 5.104 H), the formula arrived at is a molecular formula. It is also (coincidently) the empirical formula.

7. Ten grams of ice at -15 deg.C are mixed with two grams of steam at 115 deg.C. What is the final state and temperature of the mixture?

FINAL TEMPERATURE = 35.5 deg. C

FINAL STATE = liquid

8. Tetrasulfur dinitride, $S_4N_{2\,(gas)}$, reacts with molecular chlorine gas to produce sulfur dichloride, $SCl_{2\,(gas)}$, and nitrogen trichloride, $NCl_{3\,(gas)}$.

a. Write a balanced chemical equation for this reaction.

$$S_4N_{2\ (gas)} + 7\,Cl_{2(gas)} = 4\,SCl_{2\,(gas)} + 2\,NCl_{3\,(gas)}$$

b. Suppose enough chlorine gas is introduced into an empty and sealed rigid-container to result in a pressure reading of 290 torr. Then an amount of tetrasulfur dinitride is added to this same container (that already contains the chlorine gas) and the pressure reading changes to 345 torr. The reaction depicted above now takes place.

What is the total pressure of all gases remaining in the container after the reaction has gone to completion?

(All gases have the same temperature and volume, so **pressures** are *directly related* to **moles**.)

This is a limiting reagent type of problem.

Trial Calculation: How much S_4N_2 would be required to react with all of the 290 torr of molecular chlorine?

These two reagents are related by a 1 : 7 mole ratio.

So, 1 / 7 of 290 torr of S_4N_2 will react with all of the Cl_2.
Or, 41.43 torr S_4N_2. However, 55 torr are available.

Conclusion: S_4N_2 is present in an XS amount. Cl_2 is limiting.

	S_4N_2	Cl_2	SCl_2	NCl_3
B4	345-290 = 55	290	none	none
REACT 1:7:4:2	-41.43	-290	+165.71	+82.86
AFTR	13.57	none	165.71	82.86

Total pressure of all gases remaining in the container after the reaction has gone to completion...

13.57 + 0 + 165.71 + 82.86 = 262.14 torr

9. This table of standard enthalpies of formation $(kJ / mole)$ is provided for your use:

Compound	$H_2O_{(liquid)}$	$HCl_{(gas)}$	$ClO_{2\ (gas)}$	$SOCl_{2\ (gas)}$	$S_2O_5Cl_{2\ (gas)}$
ΔH_f^0	− 286	− 92	+ 98	− 176	− 162

a. Given:

$SOCl_{2\ (gas)} + 2H_2O_{\ (liquid)} = H_2SO_{3\ (liquid)} + 2HCl_{\ (gas)} \quad \Delta H^0_{Rxn} = -43\ kJ / mole$

Find ΔH_f^0 for $H_2SO_{3\ (liquid)}$

$$-43 = [\Delta H^0_{f\,(H_2SO_3)} + 2(-92)] - [(-176) + 2(-286)]$$

ΔH_f^0 for $H_2SO_{3\ (liquid)}$ = - 607 kJ / mole

b. Given: $Cl_2O_{\ (gas)} + 3/2\ O_{2\ (gas)} = 2\ ClO_{2\ (gas)} \quad \Delta H^0_{Rxn} = +120\ kJ/mole$

Find ΔH^0_{Rxn} for: $2\ H_2SO_{3\ (liquid)} + Cl_2O_{\ (gas)} = S_2O_5Cl_{2\ (gas)} + H_2O_{\ (liquid)}$

$2\ ClO_{2\ (gas)} = 3/2\ O_{2\ (gas)} + Cl_2O_{\ (gas)} \quad \Delta H^0_{Rxn}$ = - 120 kJ / mole

$2\ \{\ ½Cl_{2\ (gas)} + O_{2\ (gas)} = ClO_{2\ (gas)} \quad \Delta H_f^0$ = + 98 kJ / mole }

Combining the two above thermochemical equations yields the enthalpy of formation of $Cl_2O_{(gas)}$...

$Cl_{2\ (gas)} + ½O_{2\ (gas)} = Cl_2O_{\ (gas)} \quad \Delta H_f^0$ = + 76 kJ / mole

then,

ΔH^0_{Rxn} = [(-162) + (-286)] - [2(-607) + (+76)] = **+ 690 kJ / mole**

c. Is the sought after reaction in part B endothermic or exothermic? ENDOTHERMIC

10. An organic compound is composed of the four elements carbon, hydrogen, nitrogen and oxygen. When 2.1079 grams of the compound are burned in an excess of molecular oxygen gas then 3.5672 grams of carbon dioxide gas, 0.6254 grams of water, and 0.3243 grams of molecular nitrogen gas are produced.

Determine the empirical formula of the compound.

2.1079 g cmpd forms: 3.5672 g CO_2 0.6254 g H_2O 0.3243 g N_2

$\frac{12}{44}(3.5672) = 0.9728$ g C $\frac{2}{18}(0.6254) = 0.0695$ g H 0.3243 g N

mass oxygen in cmpd = 2.1079 – [0.9728 + 0.0695 + 0.3243] = 0.7412 g oxygen

	CARBON	HYDROGEN	NITROGEN	OXYGEN
Mass	0.9728	0.0695	0.3243	0.7412
Moles	0.9728/12= 0.08107	0.0695/1 = 0.0695	0.3243/14=0.02316	0.7412/16=0.04633
÷ by 0.02316	3.4999	3.0	1.0	2.0
× by two	7	6	2	4

Empirical formula is: $C_7H_6N_2O_4$

(A molecular formula cannot be established here,

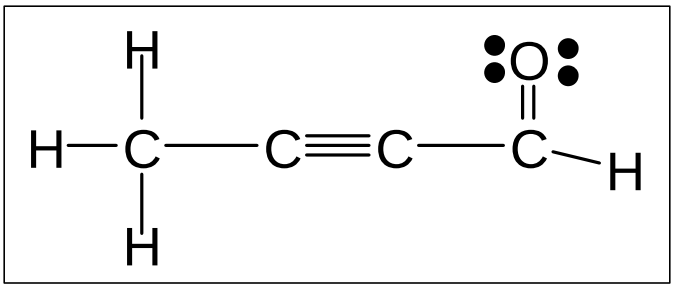
because only the **mass** of the parent compound is known,

while the number of **moles** is not.

Nor can the number of moles compound be determined from the information given..)

11. Consider the molecule shown: $CH_3 \bullet C \bullet C \bullet C(O)H$

a. Construct a Lewis dot diagram for this molecule.

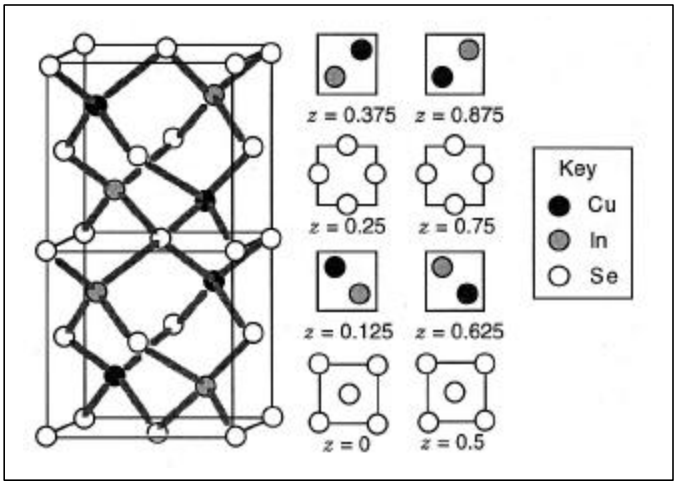


b. Complete this table of information for the molecule shown above:

	Left-most carbon	Left-center carbon	Right-center carbon	Right-most carbon
Sigma bonds	4	2	2	3
Unshared electron pairs	None	None	None	none
VSEPR formula	AX_4E_0	AX_2E_0	AX_2E_0	AX_3E_0
Basis Structure	Tetrahedron	Linear	Linear	Triangle
Reported Structure	Tetrahedron	Linear	Linear	Triangle
Bond Angles	109.5	180	180	120
Hybrid Set	sp^3	sp	sp	sp^2
Pi Bonds	None	Two	Two	One

12. A solid-state device has a unit cell composed of two FCC units joined together as shown to the right.

a. What is the chemical formula for this solid-state material?



Location	Contribution	Se	Cu	In
CORNER	1/8	8		
EDGE	1/4	4		
FACE	1/2	10		
INTERNAL	1	1	4	4
Net number of atoms In unit cell		8	4	4

The COMPLETE contents of the unit cell include 8 Se, 4 Cu, and 4 In atoms. The chemical formula of ionic compounds is the simplest ratio of these numbers, or…

$In\ Cu\ Se_2$.

Note there are FOUR of the simplest formulas in the unit cell. So the full contents may be expressed as…

(a) $In\ Cu\ Se_2$ with a multiplier of Z = 4,

or

(b) $In_4\ Cu_4\ Se_8$ with a multiplier of Z = 1.

Chemical Formula: $In\ Cu\ Se_2$ If this formula is used, then…

FW = 114.8 + 63.55 + 2(78.96) = **336.27** g /mole, AND multiplier is **Z = 4**

b. Suppose that the bottom edges of the unit cell are 6.019 D in length, and of course the height of the unit cell would be twice that length.
Determine the density of this solid-state material.

Volume cell = $(6.019)^2$ x (12.038) = 436.1 D^3

$$\text{Density} = \frac{(Z = 4)(FW = 336.27)}{(0.602)x(436.1)} = 5.123\ g / cm^3$$