Show your work in all problems to receive credit. A periodic table with useful data is included as an insert. You may use the back for scratch work but enter **ALL** work to be graded in the space provided with each question.

1) (65 points) Combustion, i.e. reaction with O_2, is often used to dispose of chemical wastes. The combustion of methyl amine, CH_3NH_2, yields nitrogen monoxide, carbon dioxide, and water.

a) Write a balanced equation for the oxidation of methyl amine.

$4\ CH_3NH_2(l)\ +\ 11\ O_2(g)\ \rightarrow\ 4\ NO(g)\ +\ 10\ H_2O(g)\ +\ 4\ CO_2(g)$

b) Calculate the mass of water produced from the complete combustion of 55 g of methyl amine.

$M(CH_3NH_2) = 1(12) + 5(1) + 1(14) = 31$ g/mole
$M(H_2O) = 1(16) + 2(1) = 18$ g/mole
$n(CH_3NH_2) = (55\ g)/(31\ g/mole) = 1.77$ mole
$n(H_2O) = (10/4)\ n(CH_3NH_2) = 4.44$ mole
$m(H_2O) = (4.44\ mole)(18\ g/mole) = 80.\ g\ (8.0 \times 10^1\ g)$

c) Calculate the number of molecules of O_2 required for the combustion.

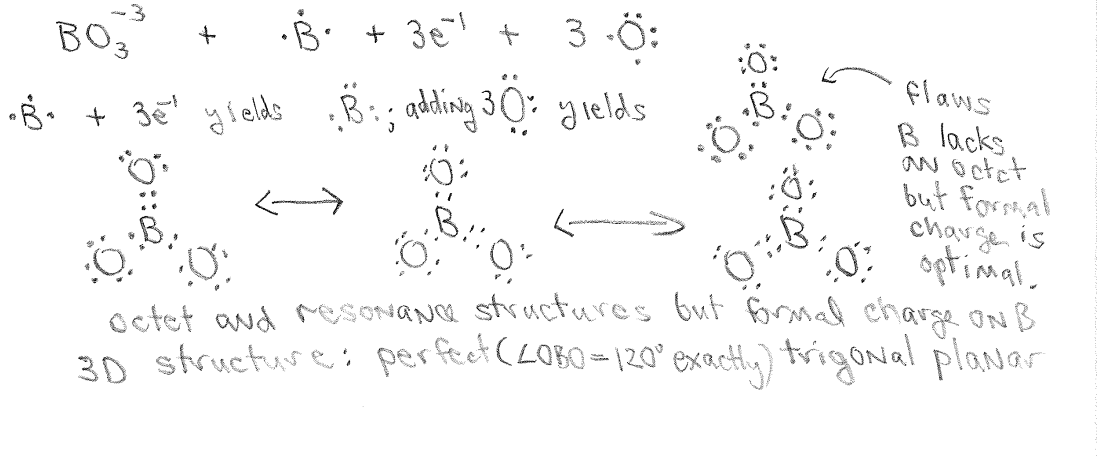
$n(O_2) = (11/4)\ n(CH_3NH_2) = 4.88$ mole
$N(O_2) = N_A n(O_2) = (4.88)(6.02 \times 10^{23}) = 2.9 \times 10^{24}$ molecules

d) The engineer handling a disposal facility is provided with 5,000 L of an aqueous solution of methyl amine. In order to determine the concentration of methyl amine, the engineer collects a 25.00 mL aliquot of the solution and titrates it with 0.1000 M hydrochloric acid. The volume of the standard HCl solution at the endpoint was 35.00 mL. Calculate the molar concentration of methyl amine in the 5,000 L sample. The stoichiometry for the reaction is

$$CH_3NH_2(aq) + H^+(aq) \rightarrow CH_3NH_3^+(aq).$$

$n(CH_3NH_2) = n(H^+) = (0.03500\ L)(0.1000\ M) = 0.0035$ mole
$[CH_3NH_2)] = (0.0035\ mole)/(0.025\ L) = 0.1400\ M$

2) (22 points) Draw an optimal Lewis electron dot formula for the borate anion, BO_3^{-3}, and predict its three-dimensional geometry.



3) (20 points) Lemons are often served with fish because fish often contain very smelly amines such as methyl amine. The acid in lemon juice converts the methyl amine to a cation, $CH_3NH_3^+$. The unmodified amine has a detectable odor whereas its salts such as CH_3NH_3Cl are odorless. Account for this striking difference in odor.

CH_3NH_2 is a covalently bonded compound of non-metals with very weak intermolecular forces and therefore a high vapor pressure. A salt such as CH_3NH_3Cl has elements of ionic bonding, i.e. the forces between the $CH_3NH_3^+$ cation and the Cl- anion. These forces which constitute ionic bonding are very strong and the salt has a very low vapor pressure. There are therefore few species in the gas phase to detect with the nose.

4) (8 points) Provide the empirical formula for the compounds formed between the following pairs of elements. Also, provide their IUPAC names.

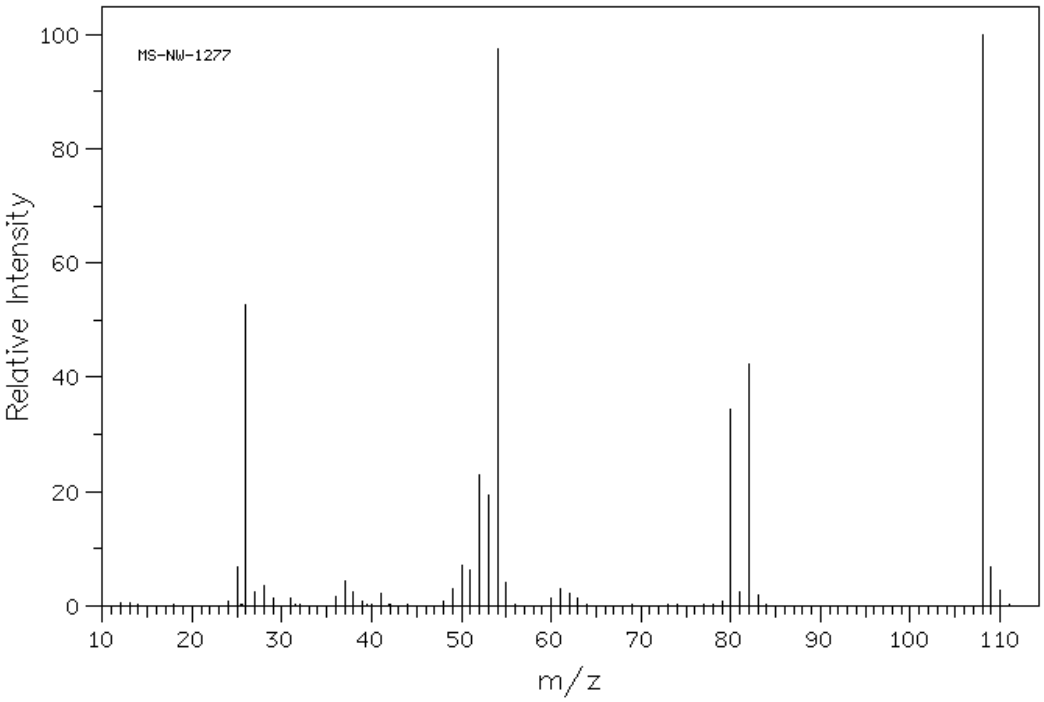
a) Mg and F Mg_2F, magnesium fluoride
b) Al and S Al_2S3, aluminum sulfide

5) (25 points) Which of the following chlorine compounds is most likely to illustrate covalent bonding? Briefly explain why. Also provide its three-dimensional structure. Compound set: $FeCl_3$, $AsCl_3$, and $BrCl_3$.

Iron is a metal and arsenic is a metalloid. Their bonding will be ionic or largely ionic. Bromine is a clear cut non-metal, lying at the far right of the periodic table. Hence its bonding will be predominantly covalent. Chlorine and bromine belong to the same family and have 7 valence electrons. One can attach one chlorine atom to the bromine. Extended valence is required to attach 3 chlorine atoms to the bromine. To achieve this, one breaks up one of the 3 lone pairs on the bromine and thereby can attach two more chlorine atoms. One ends up with 5 groups of charge, 3 bonding pairs and 2 lone pairs.

A trigonal bipyramidal structure is expected. The minimize lone pair-bonding pair and lone pair-lone pair interaction, a T shaped structure with the lone pairs on the equator, two F's on the axis, and the third F on the equator is expected to have the lowest energy.

6) (40 points) A yellow compound was isolated from the leaves of a plant. Its composition was determined by combustion analysis to be 66.7 wgt-% C, 3.7 wgt-% H, and 29.6 wgt-% O. The mass spectrum of the compound is given below. Determine the empirical formula and the molecular formula of the compound.



Source: SDBS, http://riodb01.ibase.aist.go.jp/sdbs/

In 100 g of the substance, we have
C: 66.7 g ÷ 12 g/mole = 5.56 mole ÷ 1.85 mole O = 3.00 mole C/mole O
H: 3.7 g ÷ 1.0 g/mole = 3.7 mole ÷ 1.85 mole O = 2.00 mole H/mole O
O: 29.6 g ÷ 16 g/mole = 1.85 mole ÷ 1.85 mole O = 1.00 mole O/mole O

The empirical formula is therefore C_3H_2O. If this were the molecular formula, the molecular weight would be 3(12) + 2(1) + 1(*16) = 54 g/mole. The actual molecular formula will be an integral multiple n of C_3H_2O and so will the actual molecular weight. The mass spectrum of the compound show a prominent peak (the one with the largest value of m/e) at 108 amu. This is the molecular weight. 108 =n54 so n =2 and the molecular formula is $C_6H_4O_2$.

7) (20 points) Gold ores often contain silver. Provide an explanation for this concurrence. Suggest another element likely to be found in these ores.

Gold and silver belong to the same family of the periodic table, 1b, and would have similar properties. Copper, the third known member of the family, would be expected to be found with gold and silver.