Much of this final examination in General Chemistry I is about some common acids. We will discuss large - ly organic acids because you find these compounds in many foods. With your study of chemistry this semester you will be able to interpret some of the properties of these molecules.

1. (17 points) Vitamin C, $C_6H_8O_6$, is a common acid.

   (a) The ***empirical*** formula of vitamin C is _____

   (b) The molar mass of vitamin C is

   (i) 176.12 g/mol (iii) 104.1 g/mol

   (ii) 168.1 g/mol (iv) 80.12 g/mol

   (b) The weight percent of carbon in vitamin C is

   (i) 89.94%

   (ii) 69.22%

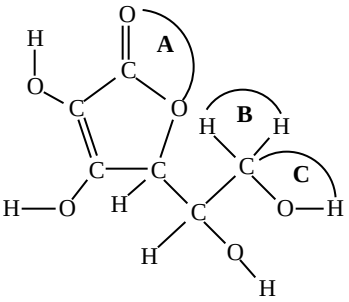
   (iii) 42.87%

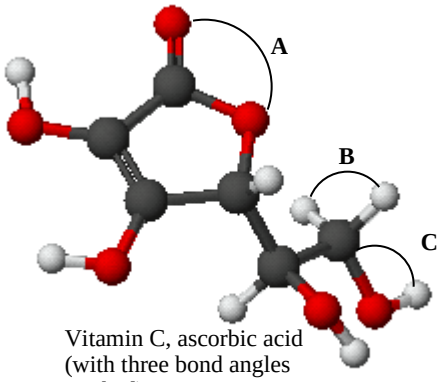
   (iv) 40.92%

   (c) The approximate values of the three bond angles marked in the structures to the right are:

   A = _____ B = _____

   C = _____





Vitamin C, ascorbic acid (with three bond angles marked)

   (d) If you have exactly 100 mg of the acid in a vitamin tablet, you have

   (i) 5.68×10^{-4} mol

   (ii) 0.568 mol

   (iii) 0.00124 mol

   (iv) 0.595 mol

   (v) none of the above

   (e) Suppose you have a 0.15 M solution of vitamin C. If you dilute 5.0 mL of the solution with water to give a new solution with a total volume of 25.0 mL, the concentration of vitamin C in the dilute solution is

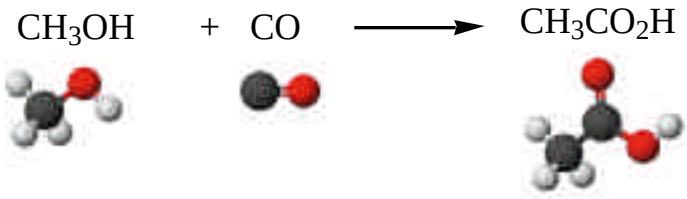
   (i) 0.030 M

   (ii) 0.075 M

   (iii) 0.15 M

   (iv) 0.75 M

2. (17 points) Acetic acid, CH_3CO_2H, can be prepared by fermentation, but the modern method of preparing it in large quantities is the catalyzed reaction of methanol, CH_3OH, and CO. (See *Chemistry & Chemical Reactivity*, page 722.)



(a) If you combine 1000 g of CH_3OH (molar mass = 32.0 g/mol) and 1000 g of CO (molar mass = 28.0 g/mol), the theoretical yield of acetic acid (molar mass = 60.05 g/mol) is

(i) 1000 g

(ii) 1877 g

(iii) 2145 g

(iv) 2000 g

(b) Suppose the theoretical yield of acetic acid from the reaction above is 1250 g. However, the reaction actually produces only 926 g. The percent yield of acetic acid is

(i) 13.5%

(ii) 50.0%

(iii) 74.1%

(iv) 81.0%

(c) What is the standard molar enthalpy change for the reaction

$$CH_3OH(\ell) + CO(g) \rightarrow CH_3CO_2H(\ell)$$

[ΔH°_f for CH_3CO_2H = -484.5 kJ/mol. The other enthalpies of formation are found in the textbook.]

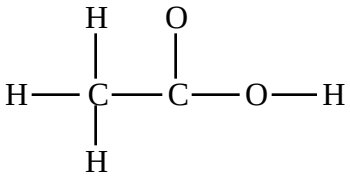
(i) ΔH°_{rxn} = -135.3 kJ

(ii) ΔH°_{rxn} = -356.3 kJ

(iii) ΔH°_{rxn} = -612.7 kJ

(iv) ΔH°_{rxn} = -833.7 kJ

(d) The acetic acid molecule has _____ valence electrons. Place any additional electron pairs into the framework here to give the *final Lewis electron dot structure* of the acid.



The H—C—H angle is _____ , the O—C—O angle is

_____. and the C—O—H angle is _____.

3. (3 points) Acid-base reactions have played a prominent role in this course. In one laboratory experiment you found the molar mass of an unknown acid. Suppose you know that your "unknown" acid is citric acid and that it has the general formula H_3A. That is, it has three H+ ions that can react with OH- ions in sodium hydroxide according to the equation

$$H_3A(aq) + 3\ NaOH(aq) \rightarrow Na_3A(aq) + 3\ H_2O(\ell)$$

What is the molar mass of citric acid (represented here by H_3A) if 0.953 g of the acid require 30.83 mL of 0.483 M NaOH?

(a) 64.0 g/mol

(b) 128 g/mol

(c) 192 g/mol

(d) 256 g/mol

(e) none of the above

4. (14 points) A salt of citric acid (see question 3 above), gallium citrate, is used in medicine as a diagnostic tool. The salt is made with radioactive Ga^{3+} ion.

(a) What is the electron configuration of gallium, Ga? (Give this configuration using the *orbital box notation* and the *noble gas abbreviation*.)

(b) What is the electron configuration of the gallium(III) ion, Ga^{3+}? (Give this configuration using the *spectroscopic notation* and the *noble gas abbreviation*.)

(c) The isotope of gallium used in medicine is ^{67}Ga. This isotope has _____ protons and _____ neutrons in the nucleus.

(d) As a Group 3A element, gallium chemistry is like that of aluminum. Thus, gallium chloride reacts with sodium hydroxide to give $Ga(OH)_3$. Balance the equation.

_____ $GaCl_3$ + _____ NaOH → _____ $Ga(OH)_3$ + _____ NaCl

The reaction is a *(redox)(acid-base)(precipitation)* reaction. _____

5. (12 points) Benzoic acid ($C_6H_5CO_2H$, molar mass = 122.1 g/mol) is found in nature and its sodium salt is often found in soft drinks. The acid can burn in air according to the equation

$$2\ C_6H_5CO_2H(s) + 15\ O_2(g) \rightarrow 14\ CO_2(g) + 6\ H_2O(\ell)$$

(a) If 3.00 g of benzoic acid burns, what quantity of O_2 is required for complete reaction?

(i) 3.00 O_2 g

(ii) 5.90 O_2 g

(iii) 11.8 O_2 g

(iv) 32.4 g O_2 g

(b) What quantity of CO_2 is produced from the combustion of 3.00 g of benzoic acid?

(i) 0.154 g CO_2

(ii) 1.08 g CO_2

(iii) 7.57 g CO_2

(iv) 15.1 g CO_2

(c) The combustion of benzoic acid is used to calibrate calorimeters. What is the enthalpy change for the reaction of benzoic acid with O_2? [ΔH°_f for solid benzoic acid = -385.2 kJ/mol]

(i) ΔH°_{rxn} = -294.1 kJ

(ii) ΔH°_{rxn} = +294.1 kJ

(iii) ΔH°_{rxn} = -6453.4 kJ

(iv) ΔH°_{rxn} = +6453.4 kJ

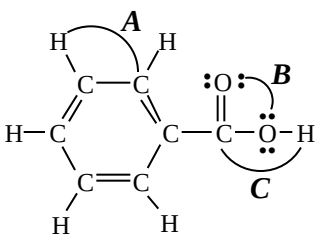
(v) ΔH°_{rxn} = -8288.3 kJ

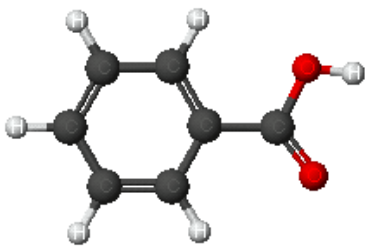
(d) Specify the approximate values for the following bond angles in benzoic acid:

A = _____

B = _____

C = _____





6. (10 points) One way to analyze a mixture for vitamin C content is to titrate the vitamin C, ascorbic acid, with bromine to give dehydroascorbic acid, $C_6H_6O_6$.

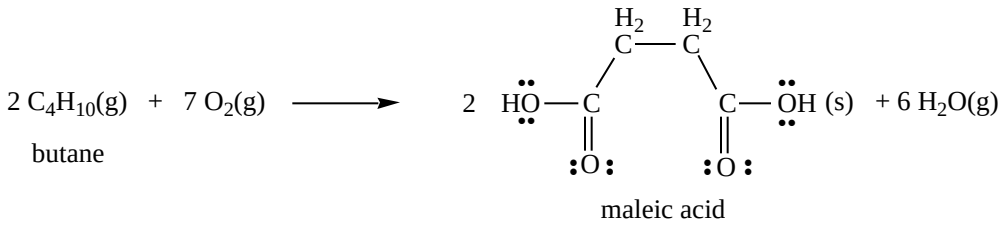
$$C_6H_8O_6(aq) + Br_2(\ell) \rightarrow C_6H_6O_6(aq) + 2\ H^+(aq) + 2\ Br^-(aq)$$

(a) Is this reaction a *(redox)(acid-base)(precipitation)* reaction? _____

(b) The reaction produces the bromide ion. Give the electron configuration using the *spectroscopic notation* (and the *noble gas abbreviation* if you wish) of the ***bromide ion***.

(c) To analyze a mixture of substances, one of which is vitamin C, you titrate a 1.035 g sample with Br_2. If you use 35.20 mL of 0.1025 M aqueous Br_2 in the titration, what is the weight percent of vitamin C (176.12 g/mol) in the 1.035 g sample? ***Show your work completely and carefully!***

7. (6 points) Maleic acid is a very important industrial chemical. Hundreds of thousands of tons are made per year. It is used in plastics for bathrooms and car bumpers, additives for vinyl flooring and mouthwashes, and in artificial sweeteners, among other things.



maleic acid

(a) If you wish to prepare 5.00 x 10^2 g of maleic acid ($C_4H_6O_4$), what quantity of butane (C_4H_{10}) would be required?

(i) 13.7 g C_4H_{10} req'd

(ii) 118 g C_4H_{10} req'd

(iii) 246 g C_4H_{10} req'd

(iv) 500 g C_4H_{10} req'd

(b) An intermediate in the maleic acid reaction is maleic anhydride, $C_4H_xO_y$. To find its formula you burn a sample in air. In such an experiment you discover that 1.056 g of maleic anhydride gives 1.602 g of CO_2 and 0.328 g of H_2O. What is the molecular formula for maleic anhydride?

$$C_4H_xO_y(s) + \text{some } O_2(g) \rightarrow 1.602 \text{ g } CO_2(g) + 0.328 \text{ g } H_2O(g)$$

(i) $C_4H_4O_4$

(ii) $C_4H_4O_6$

(iii) $C_4H_4O_8$

(iv) $C_4H_6O_6$

8. (3 points) The combustion of butane, C_4H_{10}, is exothermic; 1 mol of C_4H_{10} produces 2657 kJ of heat energy. What quantity of butane (molar mass = 58.1 g/mol) must be burned to raise the temperature of 250 g of cold water (5.0 °C) to 65 °C?

(i) 0.0236 g C_4H_{10}

(ii) 1.37 g C_4H_{10}

(iii) 2.66 g C_4H_{10}

(iv) 6.28 g C_4H_{10}

8. (28 points) Lewis electron dot structures.

(a) Draw a Lewis electron dot structure for the simple acid HOCN. (The atoms lie in a chain in the order given.)

Number of valence electrons in HOCN = _____

(b) Formic acid is the simplest organic acid. It reacts with a base to give the formate anion, HCO_2^-.

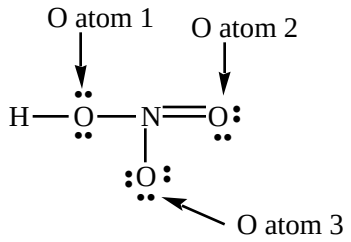
Number of valence electrons in formate anion = _____

Lewis electron dot structure of HCO_2^-, including all relevant resonance structures.

The electron pair geometry around the C atom is _____

(c) The acid HNO_3 is an important acid. Its name is _____

A Lewis electron dot structure for HNO_3 is illustrated here.



(i) The electron pair geometry around the N atom is _____

(ii) Formal charges:

O atom 1 = _____ O atom 2 = _____

O atom 3 = _____ N atom = _____

(iii) H—O—N bond angle = _____

O—N—O bond angle = _____

Draw any other resonance structures for HNO_3.

9. (24 points) Sulfur is ubiquitous in our environment and in chemical and biological systems. It forms many different types of compounds. For example,

$$Ti^{4+}(aq) + 2\ H_2S(aq) \rightarrow TiS_2(s) + 4\ H^+(aq)$$

(a) This reaction is a *(redox)(acid-base)(precipitation)* reaction. _____

(b) Titanium has an extensive chemistry, forming both Ti^{2+} and Ti^{4+} cations. Using the *orbital box notation* (and the *noble gas abbreviation*), show the electron configuration for Ti^{2+}.

Is the Ti^{2+} ion paramagnetic or diamagnetic? _____

(c) TiS_2 contains the sulfide ion. Using the *orbital box notation* (and the *noble gas abbreviation*), show the electron configuration for the ***sulfide ion***.

(d) Sulfur forms a broad range of covalent compounds with halogens.

(i) Draw the Lewis electron dot structure for SO_2.

The electron pair geometry of around S in SO_2 is _____. The molecular geometry of SO_2 is _____ and the approximate O—S—O bond angle is _____

(i) Draw the Lewis electron dot structure for OSF_4.

The electron pair geometry of around S in OSF_4 is _____.

The molecular geometry of OSF_4 is _____ and an approximate F—S—F bond angle is _____ *(indicate on your drawing which bond angle you refer to).*

10. (16 points) Periodic properties

(a) Place the following elements in order of increasing size: Al, F, S, P

_____ _____ _____ _____
smallest size *largest size*

(b) Of the elements Al, F, S, and P, which has the highest electron affinity? _____

(c) Of the elements Al, F, S, and P, which has the lowest ionization energy? _____

(d) Considering the elements Al, F, S, and P, which of the following ions are ***NOT*** likely to form? *(Circle all that apply.)*

Al^{4+} F^{-} S^{3-} P^{5+} P^{3-}

(e) Does F have an electron assigned to a 4p orbital? _____

(f) Al has an electron with a set of quantum numbers n = 3, ℓ = 1, m_ℓ = 1, and m_s = +1/2. To what type of orbital is this electron assigned (give letter designation)? _____. Sketch a picture of the boundary surface of such an orbital.

Draw the electron configuration of Al [using the *orbital box notation* and the *noble gas abbrevia - tion*] and <u>draw an arrow pointing to the electron</u> that has the set of quantum number n = 3, ℓ = 1, m_ℓ = 1, and m_s = +1/2

11. (1 point) Give us your favorite holiday recipe. What is your favorite holiday food?