1. $WO_2F_4{}^{2-}$ has two W = O double bonds and four W –F single bonds.

A. Draw Lewis Structures for 2 isomers of this anion. Label each drawing as representing a polar or a non-polar species.

B. Identify the molecular geometry of the anion, and explain why it is the same as, or different than, the electron pair geometry.

C. Are the W=O bond angles in your drawing greater than, equal to, or less than, the W-F bond angles? Answer for either drawing, and justify your answer.

D. Are the W=O bonds shorter & stronger, longer & weaker, or equivalent in length & strength to the W-F bonds? Answer for either drawing, and justify your answer.

2. The values for successive ionization energies for a certain third period element are: 578 KJ/mol; 1820 kJ/mol; 2750 kJ/mol; 11600 kJ/mol.

A. To which element do these ionization energies correspond?

B. Explain how these values confirm the element that you chose in A.

C. Estimate the third ionization energy for the element previous to the one you have chosen in A (i.e, lower atomic number), and for the element directly below (on the PT) the one you have chose in A.

3. A buffer solution composed of HX/X^- is blue when the ratio of $[HX]/[X^-] > 1$ and green when the ratio of $[HX]/[X^-] < 1$. When the ratio is exactly 1:1, the solution is colorless. Ka for HX = 1.2×10^{-3}.

A. Write a chemical equation to describe the buffer.

B. Use a particulate level illustration to represent a 1.0 M solution of HX. Include (no more than) 20 molecules of HX.

C. When the solution is colorless, what is the pH of the solution? Show appropriate calculations or equations to support your claim.

D. As a small amount of NaOH is added to the buffer solution in B, what color change will be observed? Use a chemical equation to support your claim.

E. As the solution in C is heated, it turns blue. Is the dissociation of HX an endothermic or exothermic process? Explain.

4. Solid calcium carbonate reacts with hydrochloric acid according to the equation:
$CaCO_3$ (s) + HCl (aq) → $CaCl_2$ + H_2O (ℓ) + CO_2 (g).

A. A student is attempting to determine the rate of this reaction by collecting the CO_2 gas in a large syringe. In the first experiment, the total volume of CO_2 collected increases rapidly at first, but then begins to level off. Should the student be concerned about this behavior? Justify your answer.

B. Reaction rates are typically temperature sensitive. If the collection of CO_2 is too slow, should the student increase or decrease the temperature? Provide a particulate level argument to support your answer.

C. Provide another modification the student could make that would speed up the production of CO_2 and explain, at the particulate level, how your modification would speed up the reaction.

D. What phase of calcium chloride should the student expect to produce?

5. A sample of N_2O_5, a brown gas, is introduced into a cylinder with a piston (a closed system). The gas decomposes and reaches equilibrium according to the equation:

$$N_2O_5 \text{ (g)} \leftrightarrows N_2O_3 \text{ (g)} + O_2 \text{ (g)}.$$

A. Assuming that N_2O_3 is a colorless gas, how could you determine when the system has reached equilibrium?

B. At a certain temperature, $K_p = 2.3 \times 10^{-5}$. If the equilibrium concentration of N_2O_5 = 0.12 atm, what is the partial pressure of each product at this temperature?

C. If the piston is partly withdrawn (the cylinder remains closed),

i. Will the value of Kp increase, decrease or stay the same as the piston is moving?

ii. How will the value of Kp compare to its original value (2.3×10^{-5}) once the piston has stopped moving?

D. In another experiment, conducted at the same temperature, a flask is filled with 1.1 atm N_2O_5 , 0.8 atm N_2O_3 , and 2.4 atm O_2. Will the partial pressure of oxygen increase, decrease, or stay the same as the system reaches equilibrium?

E. Explain, at the molecular level, why the total pressure in the syringe should increase if the system shifts to the right.

6. Sulfuric acid (H_2SO_4) is considered a strong acid, while sulfurous acid (H_2SO_3) is considered a weak acid. Answer the following questions about these two acids.

A. Given unlabeled 1.0 M solutions of each acid, identify two different methods of distinguishing them; be sure to explain the expected results of your tests.

B. In its most concentrated form, 99% by volume, H_2SO_4 is a non-electrolyte. In its dilute form (1.0 M), H_2SO_3 is a weak electrolyte. Based on principles of chemical structure and conductivity, explain each of these results.

C. When concentrated sulfuric acid is added to water, the water rapidly becomes extremely hot. What does this tell you about
i) the activation energy of dissolving, and
ii) the enthalpy of solution of this acid?
iii) Sketch a graph of reaction progress to display this acid dissolving in water; label the activation energy and the enthalpy of solution.

D. Compare the rate constants of the forward and reverse reactions as sulfurous acid ionizes in water.

E. Sulfurous acid decomposes to form water and a common gas; write a chemical reaction to show this reaction, and name the gas.

7. Chemistry relies on many "constants" to predict & assess the progress & process of reactions. Choose 3 of the constants and discuss what they tell us about a given reaction, under what conditions they remain constant and what we can do to change the value of these constants.

Constants: k, K, ΔG^o, ΔH^o, ΔS^o

7. Metal surfaces are often plated with a layer of chromium to improve their appearance. A student plans to plate a layer of chromium onto a piece of solid copper. The student places two strips of copper metal into a beaker containing 1.00 M chromium (III) chloride solution.

The partial list of half-cell potentials may be useful in answering the questions below:

$Cr^{2+} + 2e^- \rightarrow Cr\ (s)$ $\mathcal{E}^o = -0.91\ V$

$Cr^{3+} + 3e^- \rightarrow Cr\ (s)$ $\mathcal{E}^o = -0.74\ V$

$Cr^{3+} + e^- \rightarrow Cr^{2+}$ $\mathcal{E}^o = -0.41\ V$

$Cu^{2+} + e^- \rightarrow Cu^+$ $\mathcal{E}^o = +0.15\ V$

$Cu^{2+} + 2e^- \rightarrow Cu\ (s)$ $\mathcal{E}^o = +0.34\ V$

$Cu^+ + e^- \rightarrow Cu\ (s)$ $\mathcal{E}^o = +0.52\ V$

A. Write a balanced net ionic equation for the reaction the student is attempting to conduct.

B. Determine the standard cell potential, $\mathcal{E}^o$, for the reaction you have written

C. Determine the standard free energy change, ΔG^o, for the reaction you have written.

D. What additional component would be needed in order for this cell to become operational? Justify the need for this component in the cell.