CollegeBoard
Advanced Placement Program

AP® Chemistry
2006 Scoring Guidelines

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Question 1

1. Answer the following questions that relate to solubility of salts of lead and barium.

(a) A saturated solution is prepared by adding excess $PbI_2(s)$ to distilled water to form 1.0 L of solution at 25°C. The concentration of $Pb^{2+}(aq)$ in the saturated solution is found to be 1.3×10^{-3} M. The chemical equation for the dissolution of $PbI_2(s)$ in water is shown below.

$$PbI_2(s) \rightleftarrows Pb^{2+}(aq) + 2\,I^-(aq)$$

(i) Write the equilibrium-constant expression for the equation.

$K_{sp} = [Pb^{2+}][I^-]^2$	One point is earned for the correct expression.

(ii) Calculate the molar concentration of $I^-(aq)$ in the solution.

By stoichiometry, $[I^-] = 2 \times [Pb^{2+}]$, thus $[I^-] = 2 \times (1.3 \times 10^{-3}) = 2.6 \times 10^{-3}$ M	One point is earned for the correct concentration.

(iii) Calculate the value of the equilibrium constant, K_{sp}.

$K_{sp} = [Pb^{2+}][I^-]^2 = (1.3 \times 10^{-3})(2.6 \times 10^{-3})^2$ $= 8.8 \times 10^{-9}$	One point is earned for a value of K_{sp} that is consistent with the answers in parts (a)(i) and (a)(ii).

(b) A saturated solution is prepared by adding $PbI_2(s)$ to distilled water to form 2.0 L of solution at 25°C. What are the molar concentrations of $Pb^{2+}(aq)$ and $I^-(aq)$ in the solution? Justify your answer.

The molar concentrations of $Pb^{2+}(aq)$ and $I^-(aq)$ would be the same as in the 1.0 L solution in part (a) (i.e., 1.3×10^{-3} M and 2.6×10^{-3} M, respectively). The concentrations of solute particles in a saturated solution are a function of the constant, K_{sp}, which is independent of volume.	One point is earned for the concentrations (or stating they are the same as in the solution described in part (a)) and justification.

Question 1 (continued)

(c) Solid NaI is added to a saturated solution of PbI_2 at 25°C. Assuming that the volume of the solution does not change, does the molar concentration of $Pb^{2+}(aq)$ in the solution increase, decrease, or remain the same? Justify your answer.

$[Pb^{2+}]$ will decrease. The $NaI(s)$ will dissolve, increasing $[I^-]$; more $I^-(aq)$ then combines with $Pb^{2+}(aq)$ to precipitate $PbI_2(s)$ so that the ion product $[Pb^{2+}][I^-]^2$ will once again attain the value of 8.8×10^{-9} (K_{sp} at 25°C).	One point is earned for stating that $[Pb^{2+}]$ will decrease. One point is earned for justification (can involve a Le Chatelier argument).

(d) The value of K_{sp} for the salt $BaCrO_4$ is 1.2×10^{-10}. When a 500. mL sample of $8.2 \times 10^{-6}\ M$ $Ba(NO_3)_2$ is added to 500. mL of $8.2 \times 10^{-6}\ M$ Na_2CrO_4, no precipitate is observed.

(i) Assuming that volumes are additive, calculate the molar concentrations of $Ba^{2+}(aq)$ and $CrO_4^{2-}(aq)$ in the 1.00 L of solution.

New volume = 500. mL + 500. mL = 1.000 L, therefore $[Ba^{2+}]$ in 1.000 L is one-half its initial value: $[Ba^{2+}] = \frac{500.\text{ mL}}{1{,}000.\text{ mL}} \times (8.2 \times 10^{-6}\ M) = 4.1 \times 10^{-6}\ M$ $[CrO_4^{2-}] = \frac{500.\text{ mL}}{1{,}000.\text{ mL}} \times (8.2 \times 10^{-6}\ M) = 4.1 \times 10^{-6}\ M$	One point is earned for the correct concentration.

(ii) Use the molar concentrations of $Ba^{2+}(aq)$ ions and $CrO_4^{2-}(aq)$ ions as determined above to show why a precipitate does not form. You must include a calculation as part of your answer.

The product $Q = [Ba^{2+}][CrO_4^{2-}]$ $= (4.1 \times 10^{-6}\ M)(4.1 \times 10^{-6}\ M)$ $= 1.7 \times 10^{-11}$ Because $Q = 1.7 \times 10^{-11} < 1.2 \times 10^{-10} = K_{sp}$, no precipitate forms.	One point is earned for calculating a value of Q that is consistent with the concentration values in part (d)(i). One point is earned for using Q to explain why no precipitate forms.

Question 2

$$CO(g) + \frac{1}{2}O_2(g) \rightarrow CO_2(g)$$

2. The combustion of carbon monoxide is represented by the equation above.

(a) Determine the value of the standard enthalpy change, ΔH°_{rxn}, for the combustion of $CO(g)$ at 298 K using the following information.

$$C(s) + \frac{1}{2}O_2(g) \rightarrow CO(g) \qquad \Delta H^\circ_{298} = -110.5 \text{ kJ mol}^{-1}$$

$$C(s) + O_2(g) \rightarrow CO_2(g) \qquad \Delta H^\circ_{298} = -393.5 \text{ kJ mol}^{-1}$$

Reverse the first equation and add it to the second equation to obtain the third equation. $CO(g) \rightarrow \frac{1}{2}O_2(g) + C(s) \quad \Delta H^\circ_{298} = +110.5 \text{ kJ mol}^{-1}$ $+\ C(s) + O_2(g) \rightarrow CO_2(g) \quad \Delta H^\circ_{298} = -393.5 \text{ kJ mol}^{-1}$ $CO(g) + \frac{1}{2}O_2(g) \rightarrow CO_2(g) \quad \Delta H^\circ_{rxn} = 110.5 + (-393.5)$ $= -283.0 \text{ kJ mol}^{-1}$	One point is earned for reversing the first equation. One point is earned for the correct answer (with sign).
OR	**OR**
$\Delta H^\circ_{rxn} = \Delta H^\circ_f$ of $CO_2(g) - \Delta H^\circ_f$ of $CO(g)$ $= -393.5 \text{ kJ mol}^{-1} - (-110.5 \text{ kJ mol}^{-1}) = -283.0 \text{ kJ mol}^{-1}$	Two points are earned for determining ΔH°_{rxn} from the enthalpies of formation. (If sign is incorrect, only one point is earned.)

(b) Determine the value of the standard entropy change, ΔS°_{rxn}, for the combustion of $CO(g)$ at 298 K using the information in the following table.

Substance	S°_{298} (J mol^{-1} K^{-1})
$CO(g)$	197.7
$CO_2(g)$	213.7
$O_2(g)$	205.1

Question 2 (continued)

$\Delta S^\circ_{rxn} = 213.7 \text{ J mol}^{-1} \text{ K}^{-1} - (197.7 \text{ J mol}^{-1} \text{ K}^{-1} + \frac{1}{2}(205.1 \text{ J mol}^{-1} \text{ K}^{-1}))$ $= -86.5 \text{ J mol}^{-1} \text{ K}^{-1}$	One point is earned for taking one-half of S°_{298} for $O_2(g)$. One point is earned for the answer (with sign).

(c) Determine the standard free energy change, ΔG°_{rxn}, for the reaction at 298 K. Include units with your answer.

$\Delta G^\circ_{rxn} = \Delta H^\circ_{rxn} - T\,\Delta S^\circ_{rxn}$ $= -283.0 \text{ kJ mol}^{-1} - (298 \text{ K})(-0.0865 \text{ kJ mol}^{-1} \text{ K}^{-1})$ $\Delta G^\circ_{rxn} = -257.2 \text{ kJ mol}^{-1}$	One point is earned for substituting the values from parts (a) and (b) into the equation. One point is earned for the answer (with sign and units).

(d) Is the reaction spontaneous under standard conditions at 298 K ? Justify your answer.

Yes, the reaction is spontaneous because the value of ΔG°_{rxn} for the reaction is negative ($-257.2 \text{ kJ mol}^{-1}$).	One point is earned for an answer with justification (consistent with the answer in part (c)).

(e) Calculate the value of the equilibrium constant, K_{eq}, for the reaction at 298 K.

$\Delta G^\circ_{rxn} = -RT \ln K_{eq} \Rightarrow \frac{\Delta G^\circ_{rxn}}{-RT} = \ln K_{eq}$ $\frac{-257{,}200 \text{ J mol}^{-1}}{-(8.31 \text{ J mol}^{-1} \text{ K}^{-1})(298 \text{ K})} = \ln K_{eq} \Rightarrow K_{eq} = 1.28 \times 10^{45}$	One point is earned for correct substitution into the equation. One point is earned for the answer.

Question 3

3. Answer the following questions that relate to the analysis of chemical compounds.

(a) A compound containing the elements C, H, N, and O is analyzed. When a 1.2359 g sample is burned in excess oxygen, 2.241 g of $CO_2(g)$ is formed. The combustion analysis also showed that the sample contained 0.0648 g of H.

(i) Determine the mass, in grams, of C in the 1.2359 g sample of the compound.

$2.241\text{ g } CO_2(g) \times \frac{1\text{ mol } CO_2}{44.01\text{ g } CO_2} \times \frac{1\text{ mol C}}{1\text{ mol } CO_2} \times \frac{12.011\text{ g C}}{1\text{ mol C}}$ $= 0.6116\text{ g C}$	One point is earned for the correct answer.

(ii) When the compound is analyzed for N content only, the mass percent of N is found to be 28.84 percent. Determine the mass, in grams, of N in the original 1.2359 g sample of the compound.

$1.2359\text{ g sample} \times 0.2884 = 0.3564\text{ g N}$	One point is earned for the correct answer.

(iii) Determine the mass, in grams, of O in the original 1.2359 g sample of the compound.

Because the compound contains only C, H, N, and O, mass of O = g sample − (g H + g C + g N) $= 1.2359 - (0.0648 + 0.6116 + 0.3564) = 0.2031\text{ g}$	One point is earned for the answer consistent with the answers in parts (a)(i) and (a)(ii).

(iv) Determine the empirical formula of the compound.

Converting all masses to moles, $0.6116\text{ g C} \times \frac{1\text{ mol C}}{12.011\text{ g C}} = 0.05092\text{ mol C}$ $0.0648\text{ g H} \times \frac{1\text{ mol H}}{1.0079\text{ g H}} = 0.06429\text{ mol H}$ $0.3564\text{ g N} \times \frac{1\text{ mol N}}{14.007\text{ g N}} = 0.02544\text{ mol N}$ $0.2031\text{ g O} \times \frac{1\text{ mol O}}{16.00\text{ g O}} = 0.01269\text{ mol O}$	One point is earned for all masses converted to moles. <u>Note:</u> Moles of C may be shown in part (a)(i).

Divide all mole quantities by the smallest number of moles: $0.05092 \text{ mol} \div 0.01269 \text{ mol} = 4.013$ $0.06429 \text{ mol} \div 0.01269 \text{ mol} = 5.066$ $0.02544 \text{ mol} \div 0.01269 \text{ mol} = 2.005$ $0.01269 \text{ mol} \div 0.01269 \text{ mol} = 1.000$ $\Rightarrow$ Empirical formula is $C_4H_5N_2O$	One point is earned for dividing by the smallest number of moles. One point is earned for the empirical formula consistent with the ratio of moles calculated.

(b) A different compound, which has the empirical formula CH_2Br, has a vapor density of 6.00 g L^{-1} at 375 K and 0.983 atm. Using these data, determine the following.

(i) The molar mass of the compound

$PV = nRT \Rightarrow \frac{PV}{RT} = n$ $\frac{(0.983\text{ atm})(1.00\text{ L})}{(0.0821\text{ L atm mol}^{-1}\text{K}^{-1})(375\text{ K})} = 0.0319\text{ mol}$ molar mass of gas ($\boldsymbol{M}$) $= \frac{6.00\text{ g}}{0.0319\text{ mol}} = 188\text{ g mol}^{-1}$ *OR* $\boldsymbol{M} = \frac{DRT}{P} = \frac{6.00\text{ g L}^{-1} \times 0.0821\text{ L atm mol}^{-1}\text{ K}^{-1} \times 375\text{ K}}{0.983\text{ atm}}$ $= 188\text{ g mol}^{-1}$	One point is earned for applying the gas law to calculate *n*. One point is earned for calculating the molar mass. *OR* Two points are earned for calculating the molar mass using $\boldsymbol{M} = \frac{DRT}{P}$

(ii) The molecular formula of the compound

Each CH_2Br unit has mass of $12.011 + 2(1.0079) + 79.90 = 93.9$ g, and $\frac{188\text{ g}}{93.9\text{ g}} = 2.00$, so there must be two CH_2Br units per molecule. Therefore, the molecular formula of the compound is $C_2H_4Br_2$.	One point is earned for the molecular formula that is consistent with the molar mass calculated in part (b)(i).

Question 4

4. Write the formulas to show the reactants and the products for any FIVE of the laboratory situations described below. Answers to more than five choices will not be graded. In all cases, a reaction occurs. Assume that solutions are aqueous unless otherwise indicated. Represent substances in solution as ions if the substances are extensively ionized. Omit formulas for any ions or molecules that are unchanged by the reaction. You need not balance the equations.

General Scoring: Three points are earned for each reaction: 1 point for correct reactant(s) and 2 points for correct product(s). Designation of physical states is not required.

(a) Solid potassium chlorate is strongly heated.

$$KClO_3 \rightarrow KCl + O_2$$

(b) Solid silver chloride is added to a solution of concentrated hydrochloric acid.

$$AgCl + Cl^- \rightarrow [AgCl_2]^-$$

(c) A solution of ethanoic (acetic) acid is added to a solution of barium hydroxide.

$$HC_2H_3O_2 + OH^- \rightarrow H_2O + C_2H_3O_2^-$$

(d) Ammonia gas is bubbled into a solution of hydrofluoric acid.

$$NH_3 + HF \rightarrow NH_4^+ + F^-$$

(e) Zinc metal is placed in a solution of copper(II) sulfate.

$$Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$$

(f) Hydrogen phosphide (phosphine) gas is added to boron trichloride gas.

$$PH_3 + BCl_3 \rightarrow H_3PBCl_3$$

Note: PH_3BCl_3 also acceptable as a product.

(g) A solution of nickel(II) bromide is added to a solution of potassium hydroxide.

$$Ni^{2+} + OH^- \rightarrow Ni(OH)_2$$

(h) Hexane is combusted in air.

$$C_6H_{14} + O_2 \rightarrow CO_2 + H_2O$$

Question 5

5. Three pure, solid compounds labeled X, Y, and Z are placed on a lab bench with the objective of identifying each one. It is known that the compounds (listed in random order) are KCl, Na_2CO_3, and $MgSO_4$. A student performs several tests on the compounds; the results are summarized in the table below.

Compound	pH of an Aqueous Solution of the Compound	Result of Adding 1.0 M NaOH to a Solution of the Compound	Result of Adding 1.0 M HCl Dropwise to the Solid Compound
X	> 7	No observed reaction	Evolution of a gas
Y	7	No observed reaction	No observed reaction
Z	7	Formation of a white precipitate	No observed reaction

(a) Identify each compound based on the observations recorded in the table.

Compound X ______ Na_2CO_3 ________

Compound Y ______ KCl __________

Compound Z _____ $MgSO_4$ __________

One point is earned for one correct identification, and a second point is earned for a second correct identification. (No points are earned if all three identifications are the same compound; no second point is earned if two identifications are the same compound.)

(b) Write the chemical formula for the precipitate produced when 1.0 M NaOH is added to a solution of compound Z.

$Mg(OH)_2$	One point is earned for the correct formula.

(c) Explain why an aqueous solution of compound X has a pH value greater than 7. Write an equation as part of your explanation.

CO_3^{2-} reacts with water to form OH^-. $CO_3^{2-}(aq) + H_2O(l) \rightarrow OH^-(aq) + HCO_3^-(aq)$	One point is earned for identifying CO_3^{2-} as a base. One point is earned for a correct equation.

Question 5 (continued)

(d) One of the testing solutions used was 1.0 M NaOH. Describe the steps for preparing 100. mL of 1.0 M NaOH from a stock solution of 3.0 M NaOH using a 50 mL buret, a 100 mL volumetric flask, distilled water, and a small dropper.

1,000 mL of 1.0 M NaOH contains 1.0 mol NaOH; therefore, 100. mL of 1.0 M NaOH contains 0.10 mol NaOH (i.e., 0.10 mol NaOH is needed for the solution) volume of 3.0 M NaOH needed $= 0.10 \text{ mol NaOH} \times \dfrac{1{,}000 \text{ mL}}{3.0 \text{ mol NaOH}}$ $= 33$ mL	One point is earned for using the buret to dispense 33 mL of NaOH(aq).
Step 1: Use the buret to deliver 33 mL of the 3.0 M NaOH stock solution into the clean 100 mL volumetric flask. Step 2: Add distilled water to the flask until the liquid level is just below the calibration line in the neck of the flask; swirl gently to mix. Step 3: Use the small dropper to add the last amount of distilled water, drop by drop, until the bottom of the meniscus in the flask neck is level with the calibration line. Insert the stopper, and invert the flask to mix.	One point is earned for adding distilled water to the calibration mark.

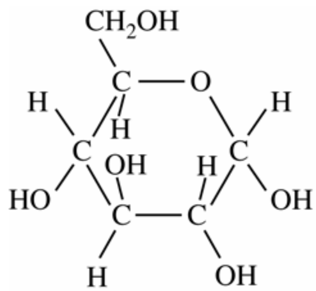
(e) Describe a simple laboratory test that you could use to distinguish between $Na_2CO_3(s)$ and $CaCO_3(s)$. In your description, specify how the results of the test would enable you to determine which compound was $Na_2CO_3(s)$ and which compound was $CaCO_3(s)$.

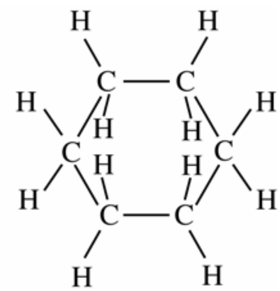
A water solubility test would work. Put a small amount of one substance in a beaker of distilled water. If the substance dissolves readily when stirred, then it is Na_2CO_3; if it does not dissolve, it is $CaCO_3$. **OR** A flame test would work. Dip a moistened wire into a sample of one of the substances and place the wire in the flame of a bunsen burner. If a bright orange-yellow color is observed, then the sample is Na_2CO_3; if a brick red color is observed, it is $CaCO_3$. <u>Note:</u> The student does NOT have to perform a confirmatory test on the other substance if one has already been identified with a test.	One point is earned for any reasonable test. One point is earned for interpreting the results that will identify one compound.

Question 6

6. Answer each of the following in terms of principles of molecular behavior and chemical concepts.

(a) The structures for glucose, $C_6H_{12}O_6$, and cyclohexane, C_6H_{12}, are shown below.





Identify the type(s) of intermolecular attractive forces in

(i) pure glucose

Hydrogen bonding OR dipole-dipole interactions OR van der Waals interactions (London dispersion forces may also be mentioned.)	One point is earned for a correct answer.

(ii) pure cyclohexane

London dispersion forces	One point is earned for London dispersion forces.

(b) Glucose is soluble in water but cyclohexane is not soluble in water. Explain.

The hydroxyl groups in glucose molecules can form strong hydrogen bonds with the solvent (water) molecules, so glucose is soluble in water. In contrast, cyclohexane is not capable of forming strong intermolecular attractions with water (no hydrogen bonding), so the water-cyclohexane interactions are not as energetically favorable as the interactions that already exist among polar water molecules. **OR** • Glucose is polar and cyclohexane is nonpolar. • Polar solutes (such as glucose) are generally soluble in polar solvents such as water. • Nonpolar solutes (such as cyclohexane) are not soluble in the polar solvent.	One point is earned for explaining the solubility of glucose in terms of hydrogen bonding or dipole-dipole interactions with water. One point is earned for explaining the difference in the polarity of cyclohexane and water. **OR** One point is earned for any one of the three concepts; two points are earned for any two of the three concepts.

Question 6 (continued)

(c) Consider the two processes represented below.

Process 1: $H_2O(l) \rightarrow H_2O(g)$ $\Delta H° = +44.0 \text{ kJ mol}^{-1}$

Process 2: $H_2O(l) \rightarrow H_2(g) + \frac{1}{2} O_2(g)$ $\Delta H° = +286 \text{ kJ mol}^{-1}$

(i) For each of the two processes, identify the type(s) of intermolecular or intramolecular attractive forces that must be overcome for the process to occur.

In process 1, hydrogen bonds (or dipole-dipole interactions) in liquid water are overcome to produce distinct water molecules in the vapor phase. In process 2, covalent bonds (or sigma bonds, or electron-pair bonds) within water molecules must be broken to allow the atoms to recombine into molecular hydrogen and oxygen.	One point is earned for identifying the type of intermolecular force involved in process 1. One point is earned for identifying the type of intramolecular bonding involved in process 2.

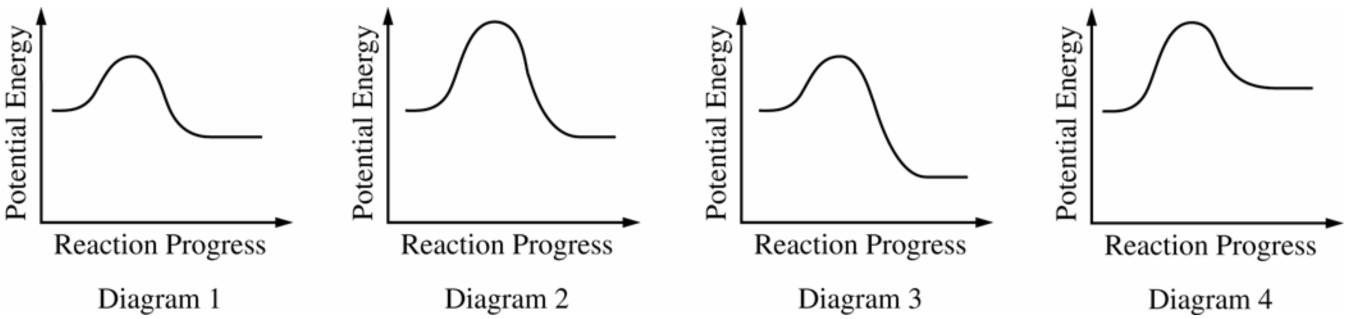
(ii) Indicate whether you agree or disagree with the statement in the box below. Support your answer with a short explanation.

When water boils, H_2O molecules break apart to form hydrogen molecules and oxygen molecules.

I disagree with the statement. Boiling is simply Process 1, in which only intermolecular forces are broken and the water molecules stay intact. No intramolecular or covalent bonds break in this process.	One point is earned for disagreeing with the statement <u>and</u> providing a correct explanation.

Question 6 (continued)

(d) Consider the four reaction-energy profile diagrams shown below.



(i) Identify the two diagrams that could represent a catalyzed and an uncatalyzed reaction pathway for the same reaction. Indicate which of the two diagrams represents the catalyzed reaction pathway for the reaction.

Diagram 1 represents a catalyzed pathway and diagram 2 represents an uncatalyzed pathway for the same reaction.	One point is earned for identifying the correct graphs and indicating which represents which pathway.

(ii) Indicate whether you agree or disagree with the statement in the box below. Support your answer with a short explanation.

Adding a catalyst to a reaction mixture adds energy that causes the reaction to proceed more quickly.

I disagree with the statement. A catalyst does not add energy, but provides an alternate reaction pathway with a lower activation energy.	One point is earned for disagreeing with the statement and providing an explanation.

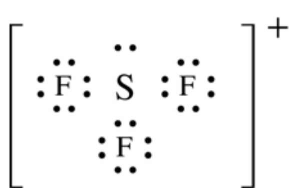
Question 7

7. Answer the following questions about the structures of ions that contain only sulfur and fluorine.

(a) The compounds SF_4 and BF_3 react to form an ionic compound according to the following equation.

$$SF_4 + BF_3 \rightarrow SF_3BF_4$$

(i) Draw a complete Lewis structure for the SF_3^+ cation in SF_3BF_4.

	One point is earned for the correct Lewis structure (the structure must include lone pairs of electrons, which may be represented as dashes).

(ii) Identify the type of hybridization exhibited by sulfur in the SF_3^+ cation.

sp^3	One point is earned for the correct hybridization.

(iii) Identify the geometry of the SF_3^+ cation that is consistent with the Lewis structure drawn in part (a)(i).

Trigonal pyramidal	One point is earned for the correct shape.

(iv) Predict whether the F–S–F bond angle in the SF_3^+ cation is larger than, equal to, or smaller than 109.5°. Justify your answer.

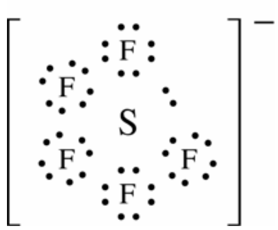
The F–S–F bond angle in the SF_3^+ cation is expected to be slightly <u>smaller</u> than 109.5° because the repulsion between the nonbonding pair of electrons and the S–F bonding pairs of electrons "squeezes" the F–S–F bond angles together slightly.	One point is earned for stating that the angle is smaller, with justification.

Question 7 (continued)

(b) The compounds SF_4 and CsF react to form an ionic compound according to the following equation.

$$SF_4 + CsF \rightarrow CsSF_5$$

(i) Draw a complete Lewis structure for the SF_5^- anion in $CsSF_5$.

	One point is earned for the correct Lewis structure (the structure must include lone pairs of electrons, which may be represented as dashes).

(ii) Identify the type of hybridization exhibited by sulfur in the SF_5^- anion.

sp^3d^2	One point is earned for the correct hybridization.

(iii) Identify the geometry of the SF_5^- anion that is consistent with the Lewis structure drawn in part (b)(i).

Square pyramidal	One point is earned for the correct shape.

(iv) Identify the oxidation number of sulfur in the compound $CsSF_5$.

+ 4	One point is earned for the correct oxidation number.

Question 8

8. Suppose that a stable element with atomic number 119, symbol Q, has been discovered.

(a) Write the ground-state electron configuration for Q, showing only the valence-shell electrons.

$8s^1$	One point is earned for the electron configuration.

(b) Would Q be a metal or a nonmetal? Explain in terms of electron configuration.

It would be a metal (**OR** an alkali metal). The valence electron would be held only loosely.	One point is earned for the correct answer and explanation, which must include reference to the valence electron.

(c) On the basis of periodic trends, would Q have the largest atomic radius in its group or would it have the smallest? Explain in terms of electronic structure.

It would have the largest atomic radius in its group because its valence electron is in a higher principal shell.	One point is earned for the correct answer and explanation; the size must refer to number of electron shells.

(d) What would be the most likely charge of the Q ion in stable ionic compounds?

+ 1	One point is earned for the correct charge. (Must be consistent with configuration in part (a).)

(e) Write a balanced equation that would represent the reaction of Q with water.

$2\ Q(s) + 2\ H_2O(l) \rightarrow 2\ Q^+(aq) + 2\ OH^-(aq) + H_2(g)$	One point is earned for H_2 as a product. One point is earned for balancing the equation.

(f) Assume that Q reacts to form a carbonate compound.

(i) Write the formula for the compound formed between Q and the carbonate ion, CO_3^{2-}.

Q_2CO_3	One point is earned for the formula consistent with the charge given in part (d).

(ii) Predict whether or not the compound would be soluble in water. Explain your reasoning.

It would be soluble in water because all alkali metal carbonates are soluble.	One point is earned for the answer consistent with the identification of Q.