AP® Chemistry
2005 Scoring Guidelines

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Question 1

$$HC_3H_5O_2(aq) \rightleftarrows C_3H_5O_2^-(aq) + H^+(aq) \qquad K_a = 1.34 \times 10^{-5}$$

Propanoic acid, $HC_3H_5O_2$, ionizes in water according to the equation above.

(a) Write the equilibrium-constant expression for the reaction.

$K_a = \dfrac{[H^+][C_3H_5O_2^-]}{[HC_3H_5O_2]}$ Notes: Correct expression without K_a earns 1 point. Entering the value of K_a is acceptable. Charges must be correct to earn 1 point.	One point is earned for the correct equilibrium expression.

(b) Calculate the pH of a 0.265 *M* solution of propanoic acid.

$HC_3H_5O_2(aq) \rightleftarrows C_3H_5O_2^-(aq) + H^+(aq)$ I: 0.265, 0, ~0 C: $-x$, $+x$, $+x$ E: $0.265 - x$, $+x$, $+x$ $K_a = \dfrac{[H^+][C_3H_5O_2^-]}{[HC_3H_5O_2]} = \dfrac{(x)(x)}{(0.265-x)}$	One point is earned for recognizing that $[H^+]$ and $[C_3H_5O_2^-]$ have the same value in the equilibrium expression.
Assume that $0.265 - x \approx 0.265$, then $1.34 \times 10^{-5} = \dfrac{x^2}{0.265}$ $(1.34 \times 10^{-5})(0.265) = x^2$ $3.55 \times 10^{-6} = x^2$ $x = [H^+] = 1.88 \times 10^{-3}$ *M*	One point is earned for calculating $[H^+]$.
$pH = -\log[H^+] = -\log(1.88 \times 10^{-3})$ $pH = 2.725$	One point is earned for calculating the correct pH.

Question 1 (continued)

(c) A 0.496 g sample of sodium propanoate, $NaC_3H_5O_2$, is added to a 50.0 mL sample of a 0.265 *M* solution of propanoic acid. Assuming that no change in the volume of the solution occurs, calculate each of the following.

(i) The concentration of the propanoate ion, $C_3H_5O_2^-(aq)$ in the solution

$\text{mol } NaC_3H_5O_2 = 0.496 \text{ g } NaC_3H_5O_2 \times \frac{1 \text{ mol } NaC_3H_5O_2}{96.0 \text{ g } NaC_3H_5O_2}$ $\text{mol } NaC_3H_5O_2 = 5.17 \times 10^{-3} \text{ mol } NaC_3H_5O_2 = \text{mol } C_3H_5O_2^-$ $[C_3H_5O_2^-] = \frac{\text{mol } C_3H_5O_2^-}{\text{volume of solution}} = \frac{5.17 \times 10^{-3} \text{ mol } C_3H_5O_2^-}{0.050 \text{ L}} = 0.103\ M$	One point is earned for calculating the number of moles of $NaC_3H_5O_2$. One point is earned for the molarity of the solution.

(ii) The concentration of the $H^+(aq)$ ion in the solution

$HC_3H_5O_2(aq) \rightleftarrows C_3H_5O_2^-(aq) + H^+(aq)$ I 0.265 0.103 ~0 C $-x$ $+x$ $+x$ E $0.265 - x$ $0.103 + x$ $+x$ $K_a = \frac{[H^+][C_3H_5O_2^-]}{[HC_3H_5O_2]} = \frac{(x)(0.103 + x)}{(0.265 - x)}$ Assume that $0.103 + x \approx 0.103$ and $0.265 - x \approx 0.265$ $K_a = 1.34 \times 10^{-5} = \frac{(x)(0.103)}{0.265}$ $x = [H^+] = (1.34 \times 10^{-5}) \times \frac{0.265}{0.103} = 3.45 \times 10^{-5}\ M$	One point is earned for calculating the value of $[H^+]$.

The methanoate ion, $HCO_2^-(aq)$, reacts with water to form methanoic acid and hydroxide ion, as shown in the following equation.

$$HCO_2^-(aq) + H_2O(l) \rightleftarrows HCO_2H(aq) + OH^-(aq)$$

(d) Given that $[OH^-]$ is 4.18×10^{-6} *M* in a 0.309 *M* solution of sodium methanoate, calculate each of the following.

Question 1 (continued)

(i) The value of K_b for the methanoate ion, $HCO_2^-(aq)$

$HCO_2^-(aq) + H_2O(l) \rightleftarrows HCO_2H + OH^-(aq)$ I: 0.309, -, 0, ~0 C: $-x$, -, $+x$, $+x$ E: $0.309 - x$, -, $+x$, $+x$ $x = [OH^-] = 4.18 \times 10^{-6}\ M$ $K_b = \frac{[OH^-][HCO_2H]}{[HCO_2^-]} = \frac{(x)(x)}{(0.309 - x)} = \frac{(4.18\times10^{-6})^2}{(0.309 - x)}$ x is very small ($4.18 \times 10^{-6}\ M$), therefore $0.309 - x \approx 0.309$ $K_b = \frac{(4.18\times10^{-6})^2}{0.309} = 5.65 \times 10^{-11}$	One point is earned for substituting 4.18×10^{-6} for both $[OH^-]$ and $[HCO_2H]$, and for calculating the value of K_b.

(ii) The value of K_a for methanoic acid, HCO_2H

$K_w = K_a \times K_b$ $K_a = \frac{K_w}{K_b} = \frac{1.00\times10^{-14}}{5.65\times10^{-11}}$ $K_a = 1.77 \times 10^{-4}$	One point is earned for calculating a value of K_a from the value of K_b determined in part (d)(i).

(e) Which acid is stronger, propanoic acid or methanoic acid? Justify your answer.

K_a for propanoic acid is 1.34×10^{-5}, and K_a for methanoic acid is 1.77×10^{-4}. For acids, the larger the value of K_a, the greater the strength; therefore methanoic acid is the stronger acid because $1.77 \times 10^{-4} > 1.34 \times 10^{-5}$.	One point is earned for the correct choice and explanation based on the K_a calculated for methanoic acid in part (d)(ii).

Question 2

Answer the following questions about a pure compound that contains only carbon, hydrogen, and oxygen.

(a) A 0.7549 g sample of the compound burns in $O_2(g)$ to produce 1.9061 g of $CO_2(g)$ and 0.3370 g of $H_2O(g)$.

(i) Calculate the individual masses of C, H, and O in the 0.7549 g sample.

$\text{mass}_C = 1.9061 \text{ g } CO_2 \times \left(\frac{1 \text{ mol } CO_2}{44.01 \text{ g } CO_2}\right) \times \left(\frac{1 \text{ mol C}}{1 \text{ mol } CO_2}\right) \times \left(\frac{12.01 \text{ g C}}{1 \text{ mol C}}\right)$ $= 0.5202 \text{ g C}$ $\text{mass}_H = 0.3370 \text{ g } H_2O \times \left(\frac{1 \text{ mol } H_2O}{18.016 \text{ g } H_2O}\right) \times \left(\frac{2 \text{ mol H}}{1 \text{ mol } H_2O}\right) \times \left(\frac{1.008 \text{ g H}}{1 \text{ mol H}}\right)$ $= 0.03771 \text{ g H}$ $\text{mass}_O = 0.7549 \text{ g} - 0.5202 \text{ g} - 0.03771 \text{ g} = 0.1970 \text{ g O}$	Three points total are earned: One point each for the masses (or moles) of C, H, and O.

(ii) Determine the empirical formula for the compound.

$n_C = 0.5202 \text{ g C} \times \left(\frac{1 \text{ mol C}}{12.01 \text{ g C}}\right) = 0.04331 \text{ mol C}$ $n_H = 0.03771 \text{ g H} \times \left(\frac{1 \text{ mol H}}{1.008 \text{ g H}}\right) = 0.03741 \text{ mol H}$ $n_O = 0.1970 \text{ g O} \times \left(\frac{1 \text{ mol O}}{16.00 \text{ g O}}\right) = 0.01231 \text{ mol O}$ $\left(\frac{0.04331 \text{ mol C}}{0.01231}\right) : \left(\frac{0.03741 \text{ mol H}}{0.01231}\right) : \left(\frac{0.01231 \text{ mol O}}{0.01231}\right)$ 3.518 mol C **:** 3.039 mol H **:** 1.000 mol O The empirical formula is $C_7H_6O_2$.	One point is earned for the number of moles of C, H, and O.* One point is earned for the empirical formula.* *based on the three masses as determined in part (a)(i) above

(b) A 0.5246 g sample of the compound was dissolved in 10.0012 g of lauric acid, and it was determined that the freezing point of the lauric acid was lowered by 1.68°C. The value of K_f of lauric acid is 3.90°C m^{-1}. Assume that the compound does not dissociate in lauric acid.

Question 2 (continued)

(i) Calculate the molality of the compound dissolved in the lauric acid.

$\Delta T_f = i \times K_f \times \text{molality}$ ($i = 1$ since compound does not dissociate) $\text{molality} = \dfrac{\Delta T_f}{K_f} = \dfrac{1.68°\text{C}}{3.90°\text{C}\ m^{-1}} = 0.431\ \text{molal}$	One point is earned for the correct molality.

(ii) Calculate the molar mass of the compound from the information provided.

$0.431\ \text{molal} = \dfrac{0.431\ \text{mol compound}}{1\ \text{kg lauric acid}}$ $n_{\text{compound}} = 10.0012\ \text{g lauric acid} \times \left(\dfrac{1\ \text{kg}}{1{,}000\ \text{g}}\right) \times \left(\dfrac{0.431\ \text{mol compound}}{1\ \text{kg lauric acid}}\right)$ $n_{\text{compound}} = 0.00431\ \text{mol}$ $\text{molar mass of compound} = \dfrac{0.5246\ \text{g compound}}{0.00431\ \text{mol compound}} = 122\ \text{g mol}^{-1}$	One point is earned for the molar mass of the compound.

(c) Without doing any calculations, explain how to determine the molecular formula of the compound based on the answers to parts (a)(ii) and (b)(ii).

The molar mass should be divided by (or compared to) the empirical mass to obtain a whole number. Each subscript in the empirical formula is multiplied by this whole number.	One point is earned for the explanation.

(d) Further tests indicate that a 0.10 *M* aqueous solution of the compound has a pH of 2.6. Identify the organic functional group that accounts for this pH.

Since an aqueous solution of the compound is acidic, the compound must be an organic acid. The functional group in an organic acid is the carboxyl group – COOH.	One point is earned for identifying the carboxyl group.

Question 3

Answer the following questions related to the kinetics of chemical reactions.

$$I^-(aq) + ClO^-(aq) \xrightarrow{OH^-} IO^-(aq) + Cl^-(aq)$$

Iodide ion, I^-, is oxidized to hypoiodite ion, IO^-, by hypochlorite, ClO^-, in basic solution according to the equation above. Three initial-rate experiments were conducted; the results are shown in the following table.

Experiment	$[I^-]$ (mol L^{-1})	$[ClO^-]$ (mol L^{-1})	Initial Rate of Formation of IO^- (mol L^{-1} s^{-1})
1	0.017	0.015	0.156
2	0.052	0.015	0.476
3	0.016	0.061	0.596

(a) Determine the order of the reaction with respect to each reactant listed below. Show your work.

(i) $I^-(aq)$

From experiments 1 and 2: $\dfrac{\text{rate}_2}{\text{rate}_1} = \dfrac{k[I^-]_2^x[ClO^-]_2^y}{k[I^-]_1^x[ClO^-]_1^y}$ $\dfrac{0.476}{0.156} = \dfrac{k(0.052)^x(0.015)^y}{k(0.017)^x(0.015)^y}$ $3.05 = \dfrac{(0.052)^x}{(0.017)^x} = 3.1^x$, therefore $x = 1$, The reaction is first order with respect to I^-.	One point is earned for the correct order of the reaction with respect to I^-, with justification.

(ii) $ClO^-(aq)$

From experiments 1 and 3: $\dfrac{\text{rate}_3}{\text{rate}_1} = \dfrac{k[I^-]_3^x[ClO^-]_3^y}{k[I^-]_1^x[ClO^-]_1^y}$ $\dfrac{0.596}{0.156} = \dfrac{k(0.016)^x(0.061)^y}{k(0.017)^x(0.015)^y} = \dfrac{k(0.016)^1(0.061)^y}{k(0.017)^1(0.015)^y}$ $3.82 = (0.94)\dfrac{(0.061)^y}{(0.015)^y}$ $4.06 = 4.1^y$, so $y = 1$, The reaction is first order with respect to ClO^-.	One point is earned for the correct order of the reaction with respect to ClO^-, with justification.

Question 3 (continued)

(b) For the reaction

(i) write the rate law that is consistent with the calculations in part (a);

rate $= k\,[I^-]^1\,[ClO^-]^1$	One point is earned for the correct rate law based on exponents as determined in part (a).

(ii) calculate the value of the specific rate constant, *k*, and specify units.

$k = \dfrac{\text{rate}}{[I^-]^1\,[ClO^-]^1}$ $k = \dfrac{0.156 \text{ mol L}^{-1}\text{ s}^{-1}}{(0.017 \text{ mol L}^{-1})(0.015 \text{ mol L}^{-1})}$ $k = 610 \text{ L mol}^{-1}\text{ s}^{-1}$ (or $610\ M^{-1}\text{ s}^{-1}$)	One point is earned for the value of *k*. One point is earned for the correct units (consistent with orders found).

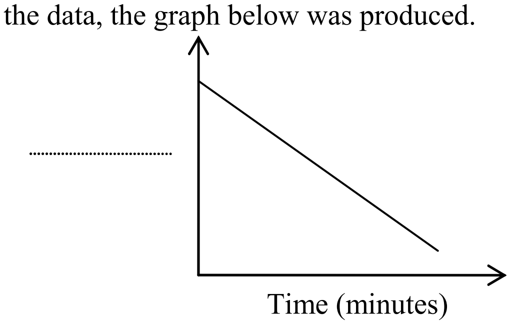
The catalyzed decomposition of hydrogen peroxide, $H_2O_2(aq)$, is represented by the following equation.

$$2\,H_2O_2(aq) \xrightarrow{\text{catalyst}} 2\,H_2O(l) + O_2(g)$$

The kinetics of the decomposition reaction were studied and the analysis of the results show that it is a first-order reaction. Some of the experimental data are shown in the table below.

$[H_2O_2]$ (mol L^{-1})	Time (minutes)
1.00	0.0
0.78	5.0
0.61	10.0

(c) During the analysis of the data, the graph below was produced.



Question 3 (continued)

(i) Label the vertical axis of the graph.

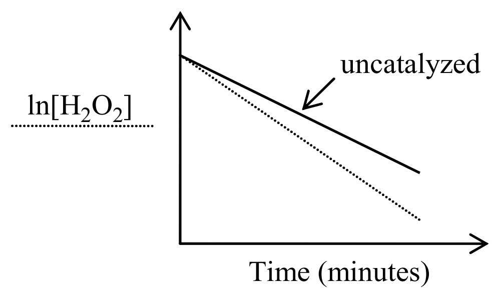
$\ln[H_2O_2]$ (or $\log[H_2O_2]$)	One point is earned for the y-axis label.

(ii) What are the units of the rate constant, k, for the decomposition of $H_2O_2(aq)$?

minutes^{-1} (or sec^{-1})	One point is earned for the correct units for k.

(iii) On the graph, draw the line that represents the plot of the uncatalyzed first-order decomposition of 1.00 M $H_2O_2(aq)$.

The line should have the same origin, be a straight line, and have a smaller negative slope.	Two points are earned for all three features (same origin, straight line, smaller negative slope), or one point for any two features.



Question 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).

(a) A strip of zinc is placed in a solution of nickel(II) nitrate.

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

(b) Solid aluminum hydroxide is added to a concentrated solution of potassium hydroxide.

$$Al(OH)_3 + OH^- \rightarrow Al(OH)_4^-$$

(c) Ethyne (acetylene) is burned in air.

$$C_2H_2 + O_2 \rightarrow CO_2 + H_2O$$

(d) Solid calcium carbonate is added to a solution of ethanoic (acetic) acid.

$$CaCO_3 + HC_2H_3O_2 \rightarrow Ca^{2+} + C_2H_3O_2^- + CO_2 + H_2O$$

(e) Lithium metal is strongly heated in nitrogen gas.

$$Li + N_2 \rightarrow Li_3N$$

(f) Boron trifluoride gas is added to ammonia gas.

$$BF_3 + NH_3 \rightarrow BF_3NH_3$$

Note: F_3BNH_3 also acceptable as a product

(g) Sulfur trioxide gas is bubbled into a solution of sodium hydroxide.

$$SO_3 + OH^- \rightarrow SO_4^{2-} + H_2O$$

Question 4 (continued)

(h) Equal volumes of 0.1 *M* solutions of lead(II) nitrate and magnesium iodide are combined.

$$Pb^{2+} + I^{-} \rightarrow PbI_2$$

Question 5

Answer the following questions that relate to laboratory observations and procedures.

(a) An unknown gas is one of three possible gases: nitrogen, hydrogen, or oxygen. For each of the three possibilities, describe the result expected when the gas is tested using a glowing splint (a wooden stick with one end that has been ignited and extinguished, but still contains hot, glowing, partially burned wood).

Nitrogen: When the glowing splint is inserted into the gas sample, the glowing splint will be extinguished. Hydrogen: When the glowing splint is inserted into the gas sample, a popping sound (explosion) can be heard. Oxygen: When the glowing splint is inserted into the gas sample, the splint will glow brighter or reignite.	One point is earned for each description.

(b) The following three mixtures have been prepared: CaO plus water, SiO_2 plus water, and CO_2 plus water. For each mixture, predict whether the pH is less than 7, equal to 7, or greater than 7. Justify your answers.

CaO plus water: The pH of the solution will be greater than 7. CaO in water forms the base $Ca(OH)_2$ (or metal oxides are basic, or basic anhydrides). SiO_2 plus water: The pH of the solution will be equal to 7. SiO_2 is insoluble in water, so there would not be a change in the pH of the mixture. CO_2 plus water: The pH of the solution will be less than 7. CO_2 in water forms the acid H_2CO_3 (or nonmetal oxides are acidic, or acidic anhydrides).	One point is earned for each description.

(c) Each of three beakers contains a 0.1 *M* solution of one of the following solutes: potassium chloride, silver nitrate, or sodium sulfide. The three beakers are labeled randomly as solution 1, solution 2, and solution 3. Shown below is a partially completed table of observations made of the results of combining small amounts of different pairs of the solutions.

Question 5 (continued)

	Solution 1	Solution 2	Solution 3
Solution 1		black precipitate	
Solution 2			no reaction
Solution 3			

(i) Write the chemical formula of the black precipitate.

The black precipitate is Ag_2S.	One point is earned for the correct formula.

(ii) Describe the expected results of mixing solution 1 with solution 3.

A precipitate will be produced when the two solutions are mixed.	One point is earned for the correct observation.

(iii) Identify each of the solutions 1, 2, and 3.

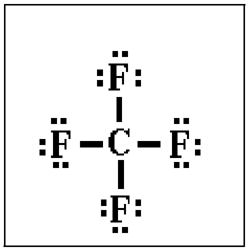
Solution 1 is silver nitrate. Solution 2 is sodium sulfide. Solution 3 is potassium chloride.	One point is earned for the correct identification of all three solutions.

Question 6

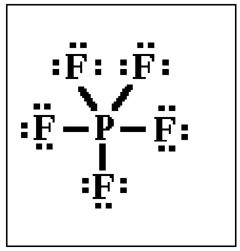
Answer the following questions that relate to chemical bonding.

(a) In the boxes provided, draw the complete Lewis structure (electron-dot diagram) for each of the three molecules represented below.

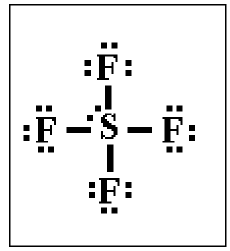
CF_4



PF_5



SF_4



See diagrams above.	One point is earned for each correct complete Lewis structure. *One point is deducted when structures are correct but nonbonding electrons around F atoms are missing.*

(b) On the basis of the Lewis structures drawn above, answer the following questions about the particular molecule indicated.

(i) What is the F–C–F bond angle in CF_4 ?

109.5° (or within range 109°–110°)	One point is earned for the correct bond angle. *The bond angle given in this part must be consistent with the Lewis structure drawn in part (a).*

(ii) What is the hybridization of the valence orbitals of P in PF_5 ?

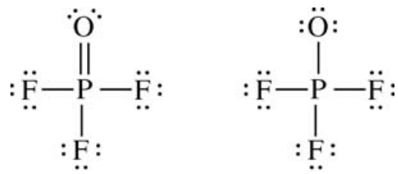
dsp^3	One point is earned for the correct hybridization. *The hybridization given in this part must be consistent with the Lewis structure drawn in part (a).*

(iii) What is the geometric shape formed by the atoms in SF_4 ?

Seesaw (or distorted tetrahedron or asymmetrical tetrahedron)	One point is earned for the correct molecular geometry. *The molecular geometry given in this part must be consistent with the Lewis structure drawn in part (a).*

Question 6 (continued)

(c) Two Lewis structures can be drawn for the OPF_3 molecule, as shown below.



Structure 1 Structure 2

(i) How many sigma bonds and how many pi bonds are in structure 1 ?

4 sigma bonds and 1 pi bond	One point is earned for the correct number of sigma bonds. One point is earned for the correct number of pi bonds.

(ii) Which one of the two structures best represents a molecule of OPF_3 ? Justify your answer in terms of formal charge.

Structure 1 is the better structure because all of its atoms have a formal charge of zero. P: $5 - 5 - 0 = 0$ F: $7 - 1 - 6 = 0$ O: $6 - 2 - 4 = 0$	One point is earned for choosing the correct structure and either (1) indicating that the formal charge is zero on P or O, or (2) showing the calculation for formal charge.

Question 7

Use principles of atomic structure, bonding, and/or intermolecular forces to respond to each of the following. Your responses <u>must</u> include specific information about <u>all</u> substances referred to in each question.

(a) At a pressure of 1 atm, the boiling point of $NH_3(l)$ is 240 K, whereas the boiling point of $NF_3(l)$ is 144 K.

(i) Identify the intermolecular forces(s) in each substance.

NH_3 has dispersion forces and hydrogen-bonding forces. NF_3 has dispersion forces and dipole-dipole forces. (Credit earned for hydrogen-bonding and dipole-dipole forces)	One point is earned for the correct intermolecular attractive forces for both NH_3 and NF_3.

(ii) Account for the difference in the boiling points of the substances.

The higher boiling point for NH_3 is due to the greater strength of the hydrogen-bonding intermolecular attractive forces among NH_3 molecules compared to that of the dipole-dipole attractive forces among NF_3 molecules.	One point is earned for correctly identifying NH_3 as having stronger intermolecular forces than NF_3.

(b) The melting point of $KCl(s)$ is 776°C, whereas the melting point of $NaCl(s)$ is 801°C.

(i) Identify the type of bonding in each substance.

Both KCl and NaCl have ionic bonds.	One point is earned for naming ionic bonds as the bonds in KCl and NaCl.

(ii) Account for the difference in the melting points of the substances.

The difference in the melting points is due to the different strengths of ionic bonding in the substances. The charges on the cations and anions are the same in both compounds, therefore the relative size of the ions is the determining factor. Since Na^+ has a smaller ionic radius than K^+, the lattice energy of NaCl is higher than that of KCl. Thus more energy is required to overcome the ionic forces in solid NaCl than in solid KCl, and NaCl has the higher melting point.	One point is earned for a correct explanation of the cause of the difference in melting points of KCl and NaCl.

Question 7 (continued)

(c) As shown in the table below, the first ionization energies of Si , P, and Cl show a trend.

Element	First Ionization Energy ($kJ\ mol^{-1}$)
Si	786
P	1,012
Cl	1,251

(i) For each of the three elements, identify the quantum level (e.g., $n = 1$, $n = 2$, etc.) of the valence electrons in the atom.

The valence electron is located in the $n = 3$ level for all three atoms.	One point is earned for the principal quantum level for all three elements.

(ii) Explain the reasons for the trend in first ionization energies.

Because the valence electrons in all three elements are shielded by the same number of inner core electrons and the nuclear charge increases going from Si to P to Cl, the valence electrons feel an increasing attraction to the nucleus going from Si to P to Cl. Valence electrons having a greater attraction to the nucleus, as in Cl , will be more difficult to remove, so Cl has the highest ionization energy. P has the second highest ionization energy, and Si has the lowest ionization energy.	One point is earned for explaining that greater ionization energy is due to increased nuclear charge. Note: Explanations of the trend on the basis of effective nuclear charge are acceptable.

(d) A certain element has two stable isotopes. The mass of one of the isotopes is 62.93 amu and the mass of the other isotope is 64.93 amu.

(i) Identify the element. Justify your answer.

Copper. The relative average atomic mass is between the two isotopic masses given.	One point is earned for the element and the explanation.

(ii) Which isotope is more abundant? Justify your answer.

The isotope with mass 62.93 amu must be more abundant because its mass is closer to 63.55 amu (the relative weighted average atomic mass for copper) than is the mass of the other isotope.	One point is earned for the correct choice and explanation.

Question 8

$$AgNO_3(s) \rightarrow Ag^+(aq) + NO_3^-(aq)$$

The dissolving of $AgNO_3(s)$ in pure water is represented by the equation above.

(a) Is ΔG for the dissolving of $AgNO_3(s)$ positive, negative, or zero? Justify your answer.

ΔG for the dissolving of $AgNO_3(s)$ is negative. Because $AgNO_3(s)$ is known to be soluble in water, the solution process must be spontaneous, therefore ΔG is negative.	One point is earned for the correct sign of ΔG and a correct explanation.

(b) Is ΔS for the dissolving of $AgNO_3(s)$ positive, negative, or zero? Justify your answer.

ΔS is positive because the solid reactant $AgNO_3(s)$ is more ordered than the aqueous ion products, $Ag^+(aq)$ and $NO_3^-(aq)$.	One point is earned for the correct sign of ΔS and a correct explanation.

(c) The solubility of $AgNO_3(s)$ increases with increasing temperature.

(i) What is the sign of ΔH for the dissolving process? Justify your answer.

The sign of ΔH must be positive for the solubility of $AgNO_3$ to increase with increasing temperature. Solubility is an equilibrium process, and since increasing temperature (accomplished by adding heat) shifts the equilibrium towards the products side in the chemical equation, heat must be absorbed during the solution process. Therefore, the solution process is endothermic, and $\Delta H > 0$.	One point is earned for the correct sign of ΔH and a correct explanation.

(ii) Is the answer you gave in part (a) consistent with your answers to parts (b) and (c)(i) ? Explain.

Yes. Although ΔH is positive, ΔS is also positive; thus ΔG can be negative because the value of the $T\Delta S$ term in the equation $\Delta G = \Delta H - T\Delta S$ is positive and can be greater than the value of the ΔH term. A positive number minus a greater positive number yields a negative number for the value of ΔG.	One point is earned for the correct sign and a correct explanation.

The compound NaI dissolves in pure water according to the equation $NaI(s) \rightarrow Na^+(aq) + I^-(aq)$. Some of the information in the table of standard reduction potentials given below may be useful in answering the questions that follow.

Question 8 (continued)

Half-reaction	E° (V)
$O_2(g) + 4\ H^+ + 4\ e^- \rightarrow 2\ H_2O(l)$	1.23
$I_2(s) + 2\ e^- \rightarrow 2\ I^-$	0.53
$2\ H_2O(l) + 2\ e^- \rightarrow H_2(g) + 2\ OH^-$	–0.83
$Na^+ + e^- \rightarrow Na(s)$	–2.71

(d) An electric current is applied to a 1.0 M NaI solution.

(i) Write the balanced oxidation half-reaction for the reaction that takes place.

$2\ I^- \rightarrow I_2(s) + 2\ e^-$	One point is earned for the correct half-reaction.

(ii) Write the balanced reduction half-reaction for the reaction that takes place.

$2\ H_2O(l) + 2\ e^- \rightarrow H_2(g) + OH^-$	One point is earned for the correct half-reaction.

(iii) Which reaction takes place at the anode, the oxidation reaction or the reduction reaction?

The oxidation half-reaction occurs at the anode.	One point is earned for the correct choice.

(iv) All electrolysis reactions have the same sign for ΔG°. Is the sign positive or negative? Justify your answer.

The sign of ΔG for all electrolysis reactions is positive. Because electrolysis reactions are non-spontaneous, energy in the form of applied electrical current (electrical work) must be applied to make the reaction occur.	One point is earned for the correct sign of ΔG and a correct explanation.