

2015

**Answer Key for AP Chemistry
Practice Exam, Section I**

Question 1: A	Question 26: A
Question 2: C	Question 27: B
Question 3: D	Question 28: B
Question 4: A	Question 29: B
Question 5: C	Question 30: B
Question 6: C	Question 31: D
Question 7: C	Question 32: B
Question 8: B	Question 33: D
Question 9: A	Question 34: D
Question 10: D	Question 35: C
Question 11: B	Question 36: A
Question 12: B	Question 37: B
Question 13: A	Question 38: B
Question 14: A	Question 39: A
Question 15: D	Question 40: B
Question 16: B	Question 41: C
Question 17: C	Question 42: B
Question 18: B	Question 43: B
Question 19: B	Question 44: B
Question 20: B	Question 45: B
Question 21: D	Question 46: C
Question 22: B	Question 47: A
Question 23: C	Question 48: D
Question 24: B	Question 49: D
Question 25: C	Question 50: D

1. A - lighter gas
2. ~~D~~ C - biggest charge difference, smallest sig of that charge
3. D - isotopes
4. A
5. C

$$q = m \times \Delta T \times c_p$$

$$\Delta T = \frac{q}{m \times c_p} = \frac{8,400 \text{ J}}{200 \text{ g} \times 4.2 \text{ J/g}^\circ\text{C}} = 10^\circ\text{C}$$

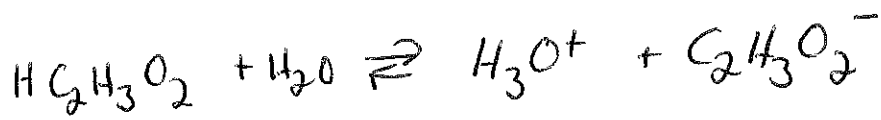
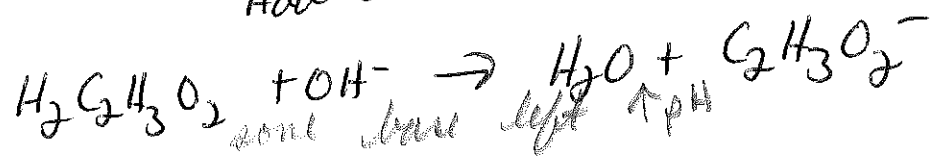
$T_f = 60^\circ\text{C}$

6. C

7. C

8. B

9. A

Add OH^- 10. ~~D~~ C

11. B

12. B

13. A

14. A

15. D

16. ~~A~~ B

17. C

$$Q = \frac{[\text{X}][\text{Y}]}{[\text{X}][\text{Y}]^2} = \frac{(0.2)(0.2)}{(0.1)^2}$$

 $Q > K_p$ more left

(27) B

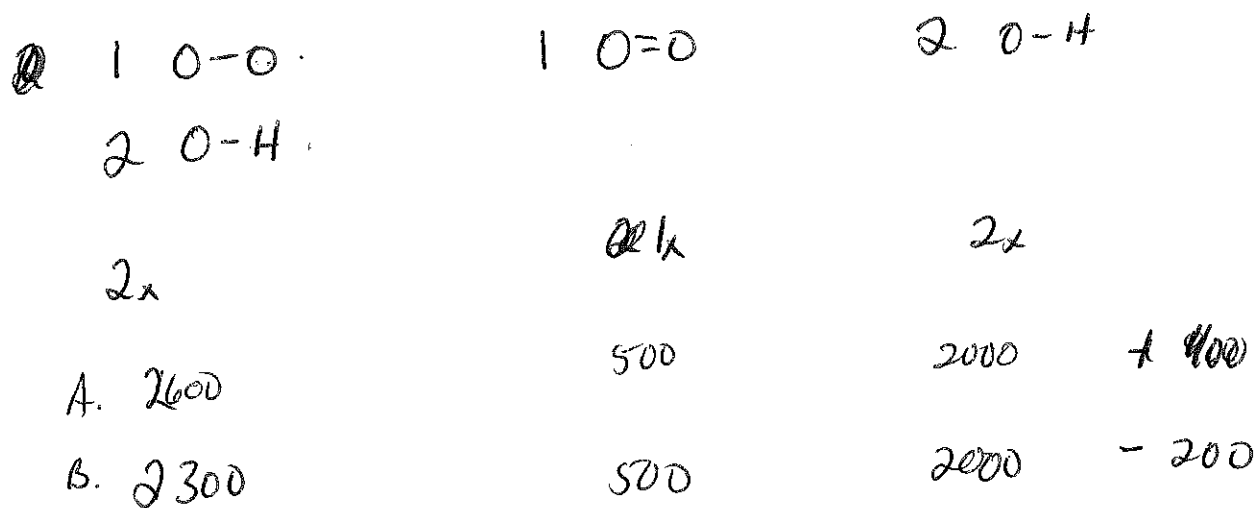
(2)

(28) $\Delta G = \Delta H - T \Delta S$
(-) (-) (+)

B

(29) B

broken - formed = (-)

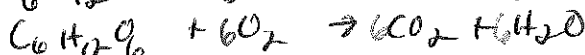


(30) B

(31) D

(32) B

$$\frac{44g}{1} \times \frac{1 \text{ mol CO}_2}{44g} \times$$
$$12gC \approx 1 \text{ mol C}$$
$$\cancel{40gO} \approx \cancel{2.5 \text{ mol O}}$$
$$5gH \approx 5 \text{ mol H}$$



[solids] remains constant, not usually part of eqbm

(3)

(39) A

(70) B

(41) C

$$.040 \times \frac{.20}{1} \times \frac{1 \text{ mol H}^+}{1 \text{ mol OH}^-} \times \frac{1}{.100} = .08 \text{ M H}^+$$

$$= .15 \text{ M H}^+$$

$$= .23 \text{ M H}^+$$

$$= .40 \text{ M}$$

(42) B

slow-step rate ~~the reactions are~~ the rate low

(73) B

two steps two bumps
lower total E (exo)

(44) B

(45) B

$$(46) C \quad K_c = \frac{[R][Z]}{[X][Q]^2}$$

(47) A bond formation

(48) B order does not
indicate how
fast $\frac{[X]}{t} = \frac{[Y]}{t}$
Y is 2x as fast

(49) D

(50) B

UV

e-transition (color)

IR vibration

mic rotation (spin)

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Question 1

Half-Reaction	E° (V)
$2 \text{CO}_2(g) + 12 \text{H}^+(aq) + 12 e^- \rightarrow \text{C}_2\text{H}_5\text{OH}(aq) + 3 \text{H}_2\text{O}(l)$	-0.085
$\text{O}_2(g) + 4 \text{H}^+(aq) + 4 e^- \rightarrow 2 \text{H}_2\text{O}(l)$	1.229

A student uses a galvanic cell to determine the concentration of ethanol, $\text{C}_2\text{H}_5\text{OH}(aq)$, in an aqueous solution. The cell is based on the half-cell reactions represented in the table above.

- (a) Write a balanced equation for the overall reaction that occurs in the cell.

$\text{C}_2\text{H}_5\text{OH}(aq) + 3 \text{O}_2(g) \rightarrow 2 \text{CO}_2(g) + 3 \text{H}_2\text{O}(l)$	<p>1 point is earned for the correct reactants and products.</p> <p>1 point is earned for balancing the equation.</p>
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- (b) Calculate E° for the overall reaction that occurs in the cell.

$E^\circ = -(-0.085 \text{ V}) + 1.229 \text{ V} = +1.314 \text{ V}$	1 point is earned for a correct answer that is consistent with the equation in part (a).
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- (c) A 10.0 mL sample of $\text{C}_2\text{H}_5\text{OH}(aq)$ is put into the electrochemical cell. The cell produces an average current of 0.10 amp for 20. seconds, at which point the $\text{C}_2\text{H}_5\text{OH}(aq)$ has been totally consumed.

- (i) Calculate the charge, in coulombs, that passed through the cell.

$I = \frac{q}{t} \Rightarrow q = It = 0.10 \text{ amp} \times 20. \text{ s} = 2.0 \text{ C}$	1 point is earned for the correct charge.
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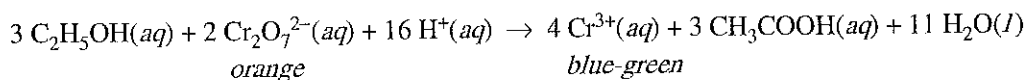
- (ii) Calculate the initial $[\text{C}_2\text{H}_5\text{OH}]$ in the solution.

$2.0 \text{ C} \times \frac{1 \text{ mol } e^-}{96,485 \text{ C}} \times \frac{1 \text{ mol } \text{C}_2\text{H}_5\text{OH}}{12 \text{ mol } e^-} = 1.7 \times 10^{-6} \text{ mol } \text{C}_2\text{H}_5\text{OH}$	1 point is earned for the number of moles of $\text{C}_2\text{H}_5\text{OH}$.
$\frac{1.7 \times 10^{-6} \text{ mol } \text{C}_2\text{H}_5\text{OH}}{10.0 \text{ mL}} \times \frac{1000 \text{ mL}}{1.0 \text{ L}} = 1.7 \times 10^{-4} \text{ M}$	1 point is earned for the initial molarity of $\text{C}_2\text{H}_5\text{OH}$.

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Question 1 (continued)

An alternative approach to determine the concentration of $\text{C}_2\text{H}_5\text{OH}(aq)$ in a solution is based on the reaction represented below.



A solution has an initial $\text{Cr}_2\text{O}_7^{2-}(aq)$ concentration of $1.0 \times 10^{-3} M$ and an initial $\text{C}_2\text{H}_5\text{OH}(aq)$ concentration of $0.500 M$. The solution contains enough strong acid to keep the pH essentially constant throughout the reaction. The student places a sample of the solution in a cuvette that has a path length of 0.50 cm and places it in a spectrophotometer set to measure absorbance at 440 nm . ($\text{Cr}_2\text{O}_7^{2-}(aq)$ is the only species in the reaction mixture that absorbs light at this wavelength.) The absorbance of $\text{Cr}_2\text{O}_7^{2-}(aq)$ in the solution is monitored as the reaction proceeds; the table below shows the absorbance as a function of time for the first trial.

Time (min)	Absorbance at 440 nm
0.00	0.782
1.50	0.553
3.00	0.389
4.50	0.278
6.00	0.194

(d) Calculate the value of $[\text{Cr}_2\text{O}_7^{2-}]$ at 1.50 min .

<p>Absorbance is proportional to $[\text{Cr}_2\text{O}_7^{2-}]$.</p> $\frac{1.0 \times 10^{-3} M}{0.782} = \frac{x}{0.553}$ $x = 7.1 \times 10^{-4} M$ <p>OR</p> <p>Initial condition: $a = \frac{A}{bc} = \frac{0.782}{(0.50 \text{ cm})(1.0 \times 10^{-3} M)} = 1564 M^{-1} \text{ cm}^{-1}$</p> <p>At 1.50 min: $c = \frac{A}{ab} = \frac{0.553}{(1564 M^{-1} \text{ cm}^{-1})(0.50 \text{ cm})} = 7.1 \times 10^{-4} M$</p>	<p>1 point is earned for the correct concentration.</p>
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Question 1 (continued)

- (e) The student runs a second trial but this time uses a cuvette that has a path length of 1.00 cm. Describe how the experimental setup should be adjusted to keep the initial absorbance at 0.782. Justify your answer with respect to the factors that influence the absorbance of a sample in a spectrophotometer.

$A = abc$ If path length (b) is doubled, and molar absorptivity (a) is constant, the initial concentration of $\text{Cr}_2\text{O}_7^{2-}$ (c) must be halved to keep the initial absorbance (A) constant.	1 point is earned for reference to a factor that affects absorbance. 1 point is earned for the correct adjustment.
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For the concentrations of reactants used in the experiment, the rate of the reaction can be written as follows.

$$\text{Rate} = k_{\text{observed}} [\text{Cr}_2\text{O}_7^{2-}]^x, \text{ where } k_{\text{observed}} = k[\text{C}_2\text{H}_5\text{OH}]$$

- (f) Explain how the experimental data indicate that the reaction is first order with respect to $\text{Cr}_2\text{O}_7^{2-}$.

Absorbance is proportional to concentration of $\text{Cr}_2\text{O}_7^{2-}$. Absorbance is halved after 3.00 min and again after another 3.00 min. Thus the half-life of the reaction is constant, so the reaction must be first order with respect to $\text{Cr}_2\text{O}_7^{2-}$. OR Demonstration that the rate of change in $\ln(A)$ over time is constant.	1 point is earned for a correct explanation that uses the data.
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Question 2

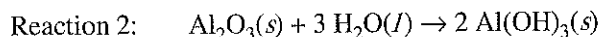
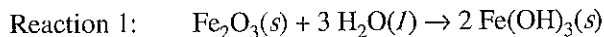
Answer the following questions about Fe and Al compounds.

- (a) $\text{Fe}_2\text{O}_3(s)$ and $\text{Al}_2\text{O}_3(s)$ have similar chemical properties; some similarities are due to the oxides having similar lattice energies. Give two reasons why the lattice energies of the oxides are similar.

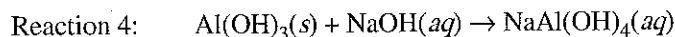
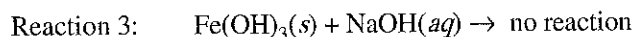
Fe^{3+} and Al^{3+} have similar sizes (radii). Fe^{3+} and Al^{3+} have the same charge.	1 point is earned for <u>each</u> reason.
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Use the following reactions that involve Fe and Al compounds to answer parts (b) and (c).

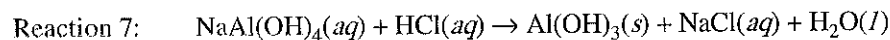
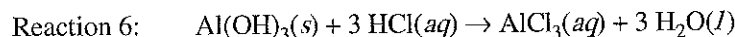
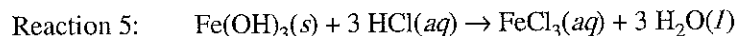
In distilled water



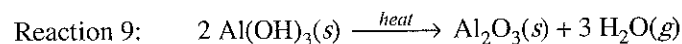
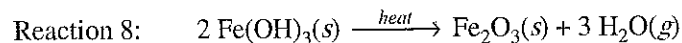
In base



In acid



When heated



Compound	K_{sp}
$\text{Fe}(\text{OH})_3$	4×10^{-38}
$\text{Al}(\text{OH})_3$	1×10^{-33}

- (b) The K_{sp} values for $\text{Fe}(\text{OH})_3$ and $\text{Al}(\text{OH})_3$ are given in the table above. A 1.0 g sample of powdered $\text{Fe}_2\text{O}_3(s)$ and a 1.0 g sample of powdered $\text{Al}_2\text{O}_3(s)$ are mixed together and placed in 1.0 L of distilled water.

- (i) Which ion, $\text{Fe}^{3+}(aq)$ or $\text{Al}^{3+}(aq)$, will be present in the higher concentration? Justify your answer with respect to the K_{sp} values provided.

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Question 2 (continued)

Al^{3+} will be present in higher concentration. $\text{Al}(\text{OH})_3$ has the same stoichiometry as $\text{Fe}(\text{OH})_3$ but a greater K_{sp} .	1 point is earned for the correct choice and explanation.
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- (ii) Write a balanced chemical equation for the dissolution reaction that results in the production of the ion that you identified in part (i).

$\text{Al}(\text{OH})_3(s) \rightarrow \text{Al}^{3+}(aq) + 3 \text{OH}^{-}(aq)$ OR $\text{Al}_2\text{O}_3(s) + 3 \text{H}_2\text{O}(l) \rightarrow 2 \text{Al}^{3+}(aq) + 6 \text{OH}^{-}(aq)$	1 point is earned for a balanced equation.
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- (c) Students are asked to develop a plan for separating $\text{Al}_2\text{O}_3(s)$ from a mixture of powdered $\text{Fe}_2\text{O}_3(s)$ and powdered $\text{Al}_2\text{O}_3(s)$ using chemical reactions and laboratory techniques.

- (i) One student proposes that $\text{Al}_2\text{O}_3(s)$ can be separated from the mixture by adding water to the mixture and then filtering. Explain why this approach is not reasonable.

This approach only works when there is a significant difference in water solubility between two substances.	1 point is earned for a correct explanation.
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- (ii) A second student organizes a plan using a table. The first two steps have already been entered in the table, as shown below. Complete the plan by listing the additional steps that are needed to recover the $\text{Al}_2\text{O}_3(s)$. List the steps in the correct order and refer to the appropriate reaction by number, if applicable.

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Question 2 (continued)

Step	Description	Reaction(s)
1	Add NaOH(aq) to convert Al ₂ O ₃ (s) to Al(OH) ₃ (s) and then to NaAl(OH) ₄ (aq).	2 and 4
2	Filter out the solid Fe(OH) ₃ from the mixture and save the filtrate.	—
3	Add HCl to the filtrate until a precipitate of Al(OH) ₃ forms.	7
4	Filter out the solid Al(OH) ₃ .	—
5	Heat the solid Al(OH) ₃ to form Al ₂ O ₃ .	9

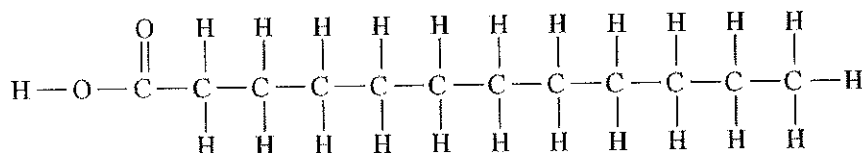
(See rows 3-5 in table.)	1 point is earned for each correct row (description plus reaction number, if applicable).
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- (iii) The second student recovers 5.5 g of Al₂O₃(s) from a 10.0 g sample of the mixture.
 Calculate the percent of Al by mass in the mixture of the two powdered oxides.
 (The molar mass of Al₂O₃ is 101.96 g/mol, and the molar mass of Fe₂O₃ is 159.70 g/mol.)

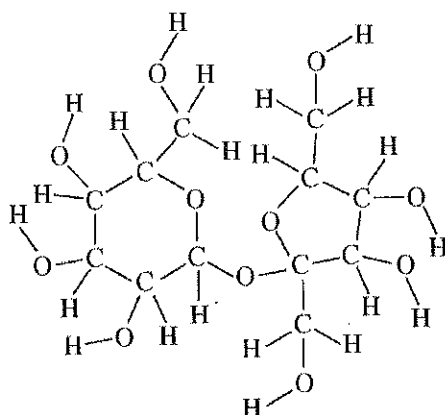
$5.5 \text{ g Al}_2\text{O}_3 \times \frac{1 \text{ mol Al}_2\text{O}_3}{101.96 \text{ g Al}_2\text{O}_3} \times \frac{2 \text{ mol Al}}{1 \text{ mol Al}_2\text{O}_3} \times \frac{26.98 \text{ g Al}}{1 \text{ mol Al}} = 2.9 \text{ g Al}$ $\frac{2.9 \text{ g}}{10.0 \text{ g}} \times 100 = 29\%$	<p>1 point is earned for the number of grams of Al.</p> <p>1 point is earned for the mass percent Al.</p>
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Question 3



Lauric Acid



Sucrose

The structures of two compounds commonly found in food, lauric acid, $C_{12}H_{24}O_2$, and sucrose, $C_{12}H_{22}O_{11}$, are shown above.

- (a) Which compound, lauric acid or sucrose, is more soluble in water? Justify your answer in terms of the intermolecular forces present between water and each of the compounds.

Sucrose is more soluble than lauric acid. Stronger interactions occur between sucrose and water molecules due to a greater capacity for hydrogen bonding as a result of a larger number of $-OH$ groups in sucrose. Although lauric acid molecules have one site for hydrogen bonding, the long hydrocarbon chain causes London dispersion forces to be the predominant, yet weaker, interaction with water molecules.

1 point is earned for discussion of hydrogen bonding between each substance and water.

1 point is earned for a valid conclusion about solubility based on a comparison of these forces.

- (b) Assume that a 1.5 g sample of lauric acid is combusted and all of the heat energy released is transferred to a 325 g sample of water initially at 25°C . Calculate the final temperature of the water if $\Delta H_{\text{combustion}}$ of lauric acid is -37 kJ/g and the specific heat of water is $4.18 \text{ J/(g}\cdot\text{K)}$.

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Question 3 (continued)

$37 \text{ kJ/g} \times 1.5 \text{ g} = 56 \text{ kJ released}$ $q = mc\Delta T \Rightarrow \Delta T = \frac{q}{mc} = \frac{56,000 \text{ J}}{(325 \text{ g})(4.18 \text{ J/(g}\cdot\text{K)})} = 41 \text{ K (41}^\circ\text{C)}$ Final temperature = $25^\circ\text{C} + 41^\circ\text{C} = 66^\circ\text{C}$	1 point is earned for heat released. 1 point is earned for a final temperature consistent with the heat released.
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- (c) In an attempt to determine $\Delta H_{\text{combustion}}$ of lauric acid experimentally, a student places a 1.5 g sample of lauric acid in a ceramic dish underneath a can made of Al containing 325 g of water at 25°C . The student ignites the sample of lauric acid with a match and records the highest temperature reached by the water in the can.

- (i) The experiment is repeated using a can of the same mass, but this time the can is made of Cu. The specific heat of Cu is $0.39 \text{ J/(g}\cdot\text{K)}$, and the specific heat of Al is $0.90 \text{ J/(g}\cdot\text{K)}$. Will the final temperature of the water in the can made of Cu be greater than, less than, or equal to the final temperature of the water in the can made of Al? Justify your answer.

The temperature will be greater in the can made of Cu. Since Cu has a lower specific heat than Al, more heat will be absorbed by the water in the Cu can than the water in the Al can.	1 point is earned for the correct answer. 1 point is earned for an appropriate explanation.
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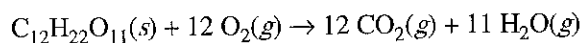
- (ii) In both experiments it was observed that the measured final temperature of the water was less than the final temperature calculated in part (b). Identify one source of experimental error that might account for this discrepancy and explain why the error would make the measured final temperature of the water lower than predicted.

Possible answers include: Heat is lost to the environment. The temperature of the water is lower because less heat is transferred to the water. OR Heat is transferred to the can or thermometer. The temperature of the water is lower because less heat is transferred to the water. OR Incomplete combustion of the lauric acid. The temperature of the water is lower because less heat was released from the combustion reaction.	1 point is earned for a valid source of error. 1 point is earned for an acceptable explanation.
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Question 3 (continued)

- (d) The experiment described above is repeated using a 1.5 g sample of sucrose. The combustion reaction for sucrose in air is represented below.



- (i) Even though ΔG° for the combustion of sucrose in air has a value of $-5837 \text{ kJ/mol}_{\text{rxn}}$, the combustion reaction does not take place unless it is ignited. Explain.

The reaction has a high activation energy. The ignition source provides energy to the molecules; some of them can then overcome the activation energy barrier. The reaction is exothermic, so the heat released allows the reaction to continue.

1 point is earned for a correct explanation.

- (ii) Predict the sign of ΔS° for the reaction and justify your prediction.

ΔS° for the reaction is positive; there are 23 moles of gaseous products for every 12 moles of gaseous reactant.

1 point is earned for the correct sign and justification.

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Question 4

Molecule	Boiling Point of Compound (K)	Dipole Moment (debyes)	Polarizability (10^{-24} cm^3)
HCl	188	1.05	2.63
HBr	207	0.80	3.61
HI	238	0.38	5.44

The boiling points, dipole moments, and polarizabilities of three hydrogen halides are given in the table above.

- (a) Based on the data in the table, what type of intermolecular force among the molecules $\text{HCl}(l)$, $\text{HBr}(l)$, and $\text{HI}(l)$ is able to account for the trend in boiling points? Justify your answer.

different
 London dispersion forces account for the trend in boiling points.
all are dipole-dipole
 As polarizability of the molecules increases, so does the boiling point of the substance.
 London dispersion forces depend upon the polarizability of molecules, thus more polarizable molecules have stronger intermolecular forces.

1 point is earned for identifying London dispersion forces.

a
 1 point is earned for explaining the link between polarizability and boiling point.

- (b) Based on the data in the table, a student predicts that the boiling point of HF should be 174 K. The observed boiling point of HF is 293 K. Explain the failure of the student's prediction in terms of the types and strengths of the intermolecular forces that exist among HF molecules.

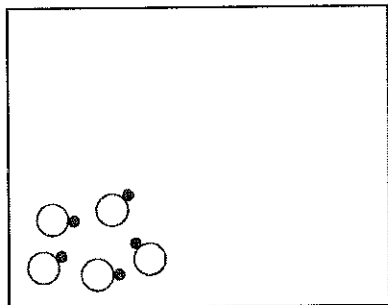
HF molecules have London dispersion forces and hydrogen bonding. The hydrogen bonding is stronger than both regular dipole-dipole forces and London dispersion forces and accounts for HF's higher boiling point.

1 point is earned for a correct explanation.

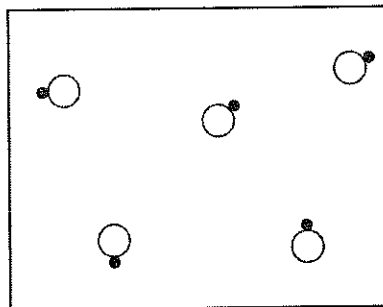
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Question 4 (continued)

- (c) A representation of five molecules of HBr in the liquid state is shown in box 1 below. In box 2, draw a representation of the five molecules of HBr after complete vaporization has occurred.



Box 1



Box 2

The drawing in Box 2 should show the undissociated molecules randomly distributed throughout the box.

1 point is earned for an acceptable diagram.

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Question 5 (continued)

- (i) Calculate the total pressure in the vessel at equilibrium at 450 K.

<p>Let n_{initial} be the number of moles of gas particles before any reaction occurs. Because 50. percent of the molecules reacted, $n_{\text{final}} = 0.75 n_{\text{initial}}$.</p> $\frac{P_{\text{initial}}}{n_{\text{initial}}} = \frac{P_{\text{final}}}{n_{\text{final}}}$ $n_{\text{CH}_3\text{COOH}} = \frac{0.020 \text{ mol}}{2} = 0.010 \text{ mol of reactant}$ $n_{(\text{CH}_3\text{COOH})_2} = \frac{0.010 \text{ mol}}{2 \text{ mol ethanol / mol product}} = 0.0050 \text{ mol of product}$ $P_{\text{final}} = \frac{(P_{\text{initial}})(n_{\text{final}})}{n_{\text{initial}}} = \frac{(0.74 \text{ atm})(0.015 \text{ mol gas particles})}{0.020 \text{ mol gas particles}} = 0.56 \text{ atm}$ <p>OR</p> $PV = nRT$ $P = \frac{(0.015 \text{ mol})(0.08206 \text{ L atm mol}^{-1} \text{ K}^{-1})(450 \text{ K})}{1.0 \text{ L}} = 0.55 \text{ atm}$	<p>1 point is earned for the correct pressure.</p>
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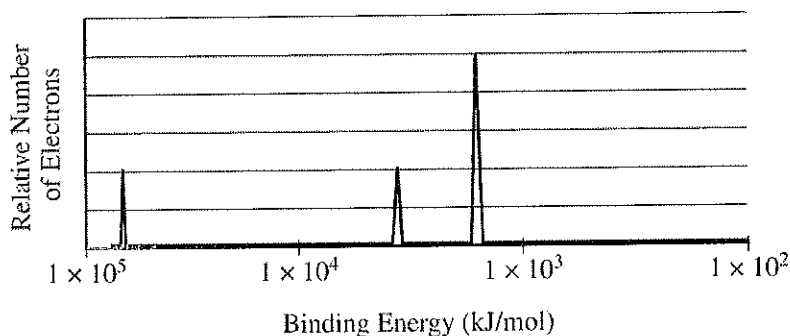
- (ii) Calculate the value of the equilibrium constant, K_p , for the reaction at 450 K.

<p>$P = 0.56 \text{ atm}$</p> <p>Mole fraction $\text{CH}_3\text{COOH} = \frac{0.010 \text{ mol}}{0.015 \text{ mol}} = \frac{2}{3}$</p> <p>Mole fraction $(\text{CH}_3\text{COOH})_2 = \frac{0.0050 \text{ mol}}{0.015 \text{ mol}} = \frac{1}{3}$</p> <p>$P_{\text{CH}_3\text{COOH}} = \frac{2}{3}(0.56 \text{ atm}) = 0.37 \text{ atm}$</p> <p>$P_{(\text{CH}_3\text{COOH})_2} = \frac{1}{3}(0.56 \text{ atm}) = 0.19 \text{ atm}$</p> <p>$K_p = \frac{(P_{(\text{CH}_3\text{COOH})_2})}{(P_{\text{CH}_3\text{COOH}})^2} = \frac{0.19}{(0.37)^2} = 1.4$</p>	<p>1 point is earned for the correct partial pressures.</p> <p>1 point is earned for an answer that uses partial pressures correctly.</p>
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Question 6

PHOTOELECTRON SPECTRUM



Peak 1	Peak 2	Peak 3
6.72×10^4 kJ/mol	3.88×10^3 kJ/mol	1.68×10^3 kJ/mol

The complete photoelectron spectrum of an unknown element is shown above. The frequency ranges of different regions of the electromagnetic spectrum are given in the table below.

Region of Electromagnetic Spectrum	Frequency Range (s^{-1})
Infrared (IR)	1×10^{12} to 4×10^{14}
Ultraviolet/visible (UV/vis)	4×10^{14} to 5×10^{16}
X-rays	5×10^{16} to 1×10^{19}
Gamma rays	$> 1 \times 10^{19}$

- (a) To generate the spectrum above, a source capable of producing electromagnetic radiation with an energy of 7×10^4 kJ per mole of photons was used. Such radiation is from which region of the electromagnetic spectrum? Justify your answer with a calculation.

$\frac{7 \times 10^4 \text{ kJ}}{1 \text{ mol photons}} \times \frac{1 \text{ mol photons}}{6.022 \times 10^{23} \text{ photons}} = 1.16 \times 10^{-19} \frac{\text{kJ}}{\text{photon}}$ $= 1 \times 10^{-19} \frac{\text{kJ}}{\text{photon}} \times \frac{1000 \text{ J}}{1 \text{ kJ}} = 1 \times 10^{-16} \frac{\text{J}}{\text{photon}}$ $\nu = \frac{E}{h} = \frac{1.16 \times 10^{-16} \text{ J}}{6.626 \times 10^{-34} \text{ J s}} = 1.75 \times 10^{17} \text{ s}^{-1} = 2 \times 10^{17} \text{ s}^{-1}$ <p>The radiation is in the X-ray region.</p>	<p>1 point is earned for calculating the amount of energy per photon.</p> <p>1 point is earned for the frequency and region of the spectrum.</p>
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Question 6 (continued)

- (b) A student examines the spectrum and proposes that the second ionization energy of the element is 3.88×10^3 kJ/mol. To refute the proposed interpretation of the spectrum, identify the following.

(i) The subshell from which an electron is removed in the second ionization of an atom of the element

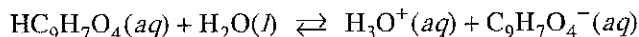
$2p$	1 point is earned for the correct answer.
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(ii) The subshell that corresponds to the second peak of the photoelectron spectrum above

$2s$	1 point is earned for the correct answer.
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Question 7



The molecular formula of acetylsalicylic acid, also known as aspirin, is $\text{HC}_9\text{H}_7\text{O}_4$. The dissociation of $\text{HC}_9\text{H}_7\text{O}_4(aq)$ is represented by the equation above. The pH of $0.0100\text{ M HC}_9\text{H}_7\text{O}_4(aq)$ is measured to be 2.78.

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

$K_a = \frac{[\text{H}_3\text{O}^+][\text{C}_9\text{H}_7\text{O}_4^-]}{[\text{HC}_9\text{H}_7\text{O}_4]}$	1 point is earned for the correct expression.
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- (b) Calculate the value of K_a for acetylsalicylic acid.

$[\text{H}_3\text{O}^+] = 10^{-\text{pH}} = 10^{-2.78} = 1.66 \times 10^{-3}\text{ M}$ $[\text{H}_3\text{O}^+] = [\text{C}_9\text{H}_7\text{O}_4^-] = 1.66 \times 10^{-3}\text{ M}$ $[\text{HC}_9\text{H}_7\text{O}_4] = 0.0100\text{ M} - 1.66 \times 10^{-3}\text{ M}$ $K_a = \frac{(1.66 \times 10^{-3})^2}{0.0100 - (1.66 \times 10^{-3})} = 3.3 \times 10^{-4}$	1 point is earned for the correct $[\text{H}_3\text{O}^+]$. 1 point is earned for the value of K_a .
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- (c) An aqueous solution of aspirin is buffered to have equal concentrations of $\text{HC}_9\text{H}_7\text{O}_4(aq)$ and $\text{C}_9\text{H}_7\text{O}_4^-(aq)$. Calculate the pH of the solution.

$\text{pH} = \text{p}K_a + \log \frac{[\text{C}_9\text{H}_7\text{O}_4^-]}{[\text{HC}_9\text{H}_7\text{O}_4]}$ $= -\log(3.3 \times 10^{-4}) + 0$ $= 3.48$	1 point is earned for a pH consistent with the K_a calculated in part (b).
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2015 AP Chemistry Scoring Worksheet

Section I: Multiple Choice

$$\frac{\text{Number Correct}}{\text{(out of 50)}} \times 1.0000 = \frac{\text{Weighted Section I Score}}{\text{(Do not round)}}$$

Section II: Free Response

$$\text{Question 1 } \frac{\text{_____}}{\text{(out of 10)}} \times 1.0869 = \frac{\text{_____}}{\text{(Do not round)}}$$

$$\text{Question 2 } \frac{\text{_____}}{\text{(out of 10)}} \times 1.0869 = \frac{\text{_____}}{\text{(Do not round)}}$$

$$\text{Question 3 } \frac{\text{_____}}{\text{(out of 10)}} \times 1.0869 = \frac{\text{_____}}{\text{(Do not round)}}$$

$$\text{Question 4 } \frac{\text{_____}}{\text{(out of 4)}} \times 1.0869 = \frac{\text{_____}}{\text{(Do not round)}}$$

$$\text{Question 5 } \frac{\text{_____}}{\text{(out of 4)}} \times 1.0869 = \frac{\text{_____}}{\text{(Do not round)}}$$

$$\text{Question 6 } \frac{\text{_____}}{\text{(out of 4)}} \times 1.0869 = \frac{\text{_____}}{\text{(Do not round)}}$$

$$\text{Question 7 } \frac{\text{_____}}{\text{(out of 4)}} \times 1.0869 = \frac{\text{_____}}{\text{(Do not round)}}$$

$$\text{Sum} = \frac{\text{_____}}{\text{Weighted Section II Score (Do not round)}}$$

Composite Score

$$\frac{\text{Weighted Section I Score}}{\text{_____}} + \frac{\text{Weighted Section II Score}}{\text{_____}} = \frac{\text{Composite Score (Round to nearest whole number)}}{\text{_____}}$$

AP Score Conversion Chart
Chemistry

Composite Score Range	AP Score
69-100	5
53-68	4
36-52	3
25-35	2
0-24	1