CollegeBoard
Advanced Placement
Program

AP® Chemistry
2010 Free-Response Questions

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INFORMATION IN THE TABLE BELOW AND IN THE TABLES ON PAGES 3-5 MAY BE USEFUL IN ANSWERING THE QUESTIONS IN THIS SECTION OF THE EXAMINATION.

DO NOT DETACH FROM BOOK.

PERIODIC TABLE OF THE ELEMENTS

1 **H** 1.008																	2 **He** 4.00
3 **Li** 6.94	4 **Be** 9.01											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
11 **Na** 22.99	12 **Mg** 24.30											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.06	17 **Cl** 35.45	18 **Ar** 39.95
19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.90	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.39	31 **Ga** 69.72	32 **Ge** 72.59	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.80
37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.94	43 **Tc** (98)	44 **Ru** 101.1	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.75	52 **Te** 127.60	53 **I** 126.91	54 **Xe** 131.29
55 **Cs** 132.91	56 **Ba** 137.33	57 ***La** 138.91	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.85	75 **Re** 186.21	76 **Os** 190.2	77 **Ir** 192.2	78 **Pt** 195.08	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.38	82 **Pb** 207.2	83 **Bi** 208.98	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** 226.02	89 **†Ac** 227.03	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (266)	107 **Bh** (264)	108 **Hs** (277)	109 **Mt** (268)	110 **Ds** (271)	111 **Rg** (272)							

*Lanthanide Series	58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** (145)	62 **Sm** 150.4	63 **Eu** 151.97	64 **Gd** 157.25	65 **Tb** 158.93	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.04	71 **Lu** 174.97
†Actinide Series	90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 **Np** (237)	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (262)

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STANDARD REDUCTION POTENTIALS IN AQUEOUS SOLUTION AT 25°C

Half-reaction			$E°$(V)
$F_2(g) + 2e^-$	→	$2F^-$	2.87
$Co^{3+} + e^-$	→	Co^{2+}	1.82
$Au^{3+} + 3e^-$	→	$Au(s)$	1.50
$Cl_2(g) + 2e^-$	→	$2Cl^-$	1.36
$O_2(g) + 4H^+ + 4e^-$	→	$2H_2O(l)$	1.23
$Br_2(l) + 2e^-$	→	$2Br^-$	1.07
$2Hg^{2+} + 2e^-$	→	$Hg_2{}^{2+}$	0.92
$Hg^{2+} + 2e^-$	→	$Hg(l)$	0.85
$Ag^+ + e^-$	→	$Ag(s)$	0.80
$Hg_2{}^{2+} + 2e^-$	→	$2Hg(l)$	0.79
$Fe^{3+} + e^-$	→	Fe^{2+}	0.77
$I_2(s) + 2e^-$	→	$2I^-$	0.53
$Cu^+ + e^-$	→	$Cu(s)$	0.52
$Cu^{2+} + 2e^-$	→	$Cu(s)$	0.34
$Cu^{2+} + e^-$	→	Cu^+	0.15
$Sn^{4+} + 2e^-$	→	Sn^{2+}	0.15
$S(s) + 2H^+ + 2e^-$	→	$H_2S(g)$	0.14
$2H^+ + 2e^-$	→	$H_2(g)$	0.00
$Pb^{2+} + 2e^-$	→	$Pb(s)$	–0.13
$Sn^{2+} + 2e^-$	→	$Sn(s)$	–0.14
$Ni^{2+} + 2e^-$	→	$Ni(s)$	–0.25
$Co^{2+} + 2e^-$	→	$Co(s)$	–0.28
$Cd^{2+} + 2e^-$	→	$Cd(s)$	–0.40
$Cr^{3+} + e^-$	→	Cr^{2+}	–0.41
$Fe^{2+} + 2e^-$	→	$Fe(s)$	–0.44
$Cr^{3+} + 3e^-$	→	$Cr(s)$	–0.74
$Zn^{2+} + 2e^-$	→	$Zn(s)$	–0.76
$2H_2O(l) + 2e^-$	→	$H_2(g) + 2OH^-$	–0.83
$Mn^{2+} + 2e^-$	→	$Mn(s)$	–1.18
$Al^{3+} + 3e^-$	→	$Al(s)$	–1.66
$Be^{2+} + 2e^-$	→	$Be(s)$	–1.70
$Mg^{2+} + 2e^-$	→	$Mg(s)$	–2.37
$Na^+ + e^-$	→	$Na(s)$	–2.71
$Ca^{2+} + 2e^-$	→	$Ca(s)$	–2.87
$Sr^{2+} + 2e^-$	→	$Sr(s)$	–2.89
$Ba^{2+} + 2e^-$	→	$Ba(s)$	–2.90
$Rb^+ + e^-$	→	$Rb(s)$	–2.92
$K^+ + e^-$	→	$K(s)$	–2.92
$Cs^+ + e^-$	→	$Cs(s)$	–2.92
$Li^+ + e^-$	→	$Li(s)$	–3.05

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ADVANCED PLACEMENT CHEMISTRY EQUATIONS AND CONSTANTS

ATOMIC STRUCTURE

$$E = h\nu \qquad c = \lambda\nu$$

$$\lambda = \frac{h}{m\upsilon} \qquad p = m\upsilon$$

$$E_n = \frac{-2.178 \times 10^{-18}}{n^2}\,\text{joule}$$

EQUILIBRIUM

$$K_a = \frac{[\text{H}^+][\text{A}^-]}{[\text{HA}]}$$

$$K_b = \frac{[\text{OH}^-][\text{HB}^+]}{[\text{B}]}$$

$$\begin{aligned} K_w &= [\text{OH}^-][\text{H}^+] = 1.0 \times 10^{-14} \text{ @ } 25^\circ\text{C} \\ &= K_a \times K_b \end{aligned}$$

$$\text{pH} = -\log[\text{H}^+],\ \text{pOH} = -\log[\text{OH}^-]$$

$$14 = \text{pH} + \text{pOH}$$

$$\text{pH} = \text{p}K_a + \log\frac{[\text{A}^-]}{[\text{HA}]}$$

$$\text{pOH} = \text{p}K_b + \log\frac{[\text{HB}^+]}{[\text{B}]}$$

$$\text{p}K_a = -\log K_a,\ \text{p}K_b = -\log K_b$$

$$K_p = K_c(RT)^{\Delta n},$$

where Δn = moles product gas − moles reactant gas

THERMOCHEMISTRY/KINETICS

$$\Delta S^\circ = \sum S^\circ \text{ products} - \sum S^\circ \text{ reactants}$$

$$\Delta H^\circ = \sum \Delta H_f^\circ \text{ products} - \sum \Delta H_f^\circ \text{ reactants}$$

$$\Delta G^\circ = \sum \Delta G_f^\circ \text{ products} - \sum \Delta G_f^\circ \text{ reactants}$$

$$\begin{aligned} \Delta G^\circ &= \Delta H^\circ - T\Delta S^\circ \\ &= -RT\ln K = -2.303\,RT\log K \\ &= -n\mathcal{F}E^\circ \end{aligned}$$

$$\Delta G = \Delta G^\circ + RT\ln Q = \Delta G^\circ + 2.303\,RT\log Q$$

$$q = mc\Delta T$$

$$C_p = \frac{\Delta H}{\Delta T}$$

$$\ln[\text{A}]_t - \ln[\text{A}]_0 = -kt$$

$$\frac{1}{[\text{A}]_t} - \frac{1}{[\text{A}]_0} = kt$$

$$\ln k = \frac{-E_a}{R}\left(\frac{1}{T}\right) + \ln A$$

E = energy
ν = frequency
λ = wavelength
p = momentum
υ = velocity
n = principal quantum number
m = mass

Speed of light, $c = 3.0 \times 10^8 \text{ m s}^{-1}$

Planck's constant, $h = 6.63 \times 10^{-34}$ J s

Boltzmann's constant, $k = 1.38 \times 10^{-23} \text{ J K}^{-1}$

Avogadro's number $= 6.022 \times 10^{23} \text{ mol}^{-1}$

Electron charge, $e = -1.602 \times 10^{-19}$ coulomb

1 electron volt per atom $= 96.5 \text{ kJ mol}^{-1}$

Equilibrium Constants

K_a (weak acid)
K_b (weak base)
K_w (water)
K_p (gas pressure)
K_c (molar concentrations)

S° = standard entropy
H° = standard enthalpy
G° = standard free energy
E° = standard reduction potential
T = temperature
n = moles
m = mass
q = heat
c = specific heat capacity
C_p = molar heat capacity at constant pressure
E_a = activation energy
k = rate constant
A = frequency factor

Faraday's constant, $\mathcal{F}$ = 96,500 coulombs per mole of electrons

$$\begin{aligned} \text{Gas constant, } R &= 8.31 \text{ J mol}^{-1}\text{ K}^{-1} \\ &= 0.0821 \text{ L atm mol}^{-1}\text{ K}^{-1} \\ &= 62.4 \text{ L torr mol}^{-1}\text{ K}^{-1} \\ &= 8.31 \text{ volt coulomb mol}^{-1}\text{ K}^{-1} \end{aligned}$$

GASES, LIQUIDS, AND SOLUTIONS

$$PV = nRT$$

$$\left(P + \frac{n^2a}{V^2}\right)(V - nb) = nRT$$

$$P_A = P_{total} \times X_A, \text{where } X_A = \frac{\text{moles A}}{\text{total moles}}$$

$$P_{total} = P_A + P_B + P_C + ...$$

$$n = \frac{m}{\boldsymbol{M}}$$

$$\text{K} = {}^\circ\text{C} + 273$$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$D = \frac{m}{V}$$

$$u_{rms} = \sqrt{\frac{3kT}{m}} = \sqrt{\frac{3RT}{\boldsymbol{M}}}$$

$$KE \text{ per molecule} = \frac{1}{2}mv^2$$

$$KE \text{ per mole} = \frac{3}{2}RT$$

$$\frac{r_1}{r_2} = \sqrt{\frac{\boldsymbol{M}_2}{\boldsymbol{M}_1}}$$

molarity, M = moles solute per liter solution

molality = moles solute per kilogram solvent

$$\Delta T_f = iK_f \times \text{molality}$$

$$\Delta T_b = iK_b \times \text{molality}$$

$$\pi = iMRT$$

$$A = abc$$

OXIDATION-REDUCTION; ELECTROCHEMISTRY

$$Q = \frac{[\text{C}]^c\,[\text{D}]^d}{[\text{A}]^a\,[\text{B}]^b}, \text{ where } a\,\text{A} + b\,\text{B} \rightarrow c\,\text{C} + d\,\text{D}$$

$$I = \frac{q}{t}$$

$$E_{\text{cell}} = E^\circ_{\text{cell}} - \frac{RT}{n\mathcal{F}}\ln Q = E^\circ_{\text{cell}} - \frac{0.0592}{n}\log Q \quad @\, 25^\circ\text{C}$$

$$\log K = \frac{nE^\circ}{0.0592}$$

P = pressure
V = volume
T = temperature
n = number of moles
D = density
m = mass
v = velocity

u_{rms} = root-mean-square speed
KE = kinetic energy
r = rate of effusion
$\boldsymbol{M}$ = molar mass
π = osmotic pressure
i = van't Hoff factor
K_f = molal freezing-point depression constant
K_b = molal boiling-point elevation constant
A = absorbance
a = molar absorptivity
b = path length
c = concentration
Q = reaction quotient
I = current (amperes)
q = charge (coulombs)
t = time (seconds)
E° = standard reduction potential
K = equilibrium constant

Gas constant, $R = 8.31 \text{ J mol}^{-1}\text{ K}^{-1}$
$= 0.0821 \text{ L atm mol}^{-1}\text{ K}^{-1}$
$= 62.4 \text{ L torr mol}^{-1}\text{ K}^{-1}$
$= 8.31 \text{ volt coulomb mol}^{-1}\text{ K}^{-1}$
Boltzmann's constant, $k = 1.38 \times 10^{-23} \text{ J K}^{-1}$
K_f for H_2O = $1.86 \text{ K kg mol}^{-1}$
K_b for H_2O = $0.512 \text{ K kg mol}^{-1}$
1 atm = 760 mm Hg
= 760 torr
STP = 0.00°C and 1.0 atm
Faraday's constant, $\mathcal{F}$ = 96,500 coulombs per mole of electrons

CHEMISTRY
Section II
(Total time—95 minutes)

Part A
Time—55 minutes
YOU MAY USE YOUR CALCULATOR FOR PART A.

CLEARLY SHOW THE METHOD USED AND THE STEPS INVOLVED IN ARRIVING AT YOUR ANSWERS. It is to your advantage to do this, since you may obtain partial credit if you do and you will receive little or no credit if you do not. Attention should be paid to significant figures.

Be sure to write all your answers to the questions on the lined pages following each question in the booklet with the pink cover. Do NOT write your answers on the green insert.

Answer Questions 1, 2, and 3. The Section II score weighting for each question is 20 percent.

1. Several reactions are carried out using AgBr, a cream-colored silver salt for which the value of the solubility-product constant, K_{sp}, is 5.0×10^{-13} at 298 K.

   (a) Write the expression for the solubility-product constant, K_{sp}, of AgBr.

   (b) Calculate the value of $[Ag^+]$ in 50.0 mL of a saturated solution of AgBr at 298 K.

   (c) A 50.0 mL sample of distilled water is added to the solution described in part (b), which is in a beaker with some solid AgBr at the bottom. The solution is stirred and equilibrium is reestablished. Some solid AgBr remains in the beaker. Is the value of $[Ag^+]$ greater than, less than, or equal to the value you calculated in part (b) ? Justify your answer.

   (d) Calculate the minimum volume of distilled water, in liters, necessary to completely dissolve a 5.0 g sample of AgBr(*s*) at 298 K. (The molar mass of AgBr is 188 g mol^{-1}.)

   (e) A student mixes 10.0 mL of 1.5×10^{-4} *M* $AgNO_3$ with 2.0 mL of 5.0×10^{-4} *M* NaBr and stirs the resulting mixture. What will the student observe? Justify your answer with calculations.

   (f) The color of another salt of silver, AgI(*s*), is yellow. A student adds a solution of NaI to a test tube containing a small amount of solid, cream-colored AgBr. After stirring the contents of the test tube, the student observes that the solid in the test tube changes color from cream to yellow.

      (i) Write the chemical equation for the reaction that occurred in the test tube.

      (ii) Which salt has the greater value of K_{sp}: AgBr or AgI ? Justify your answer.

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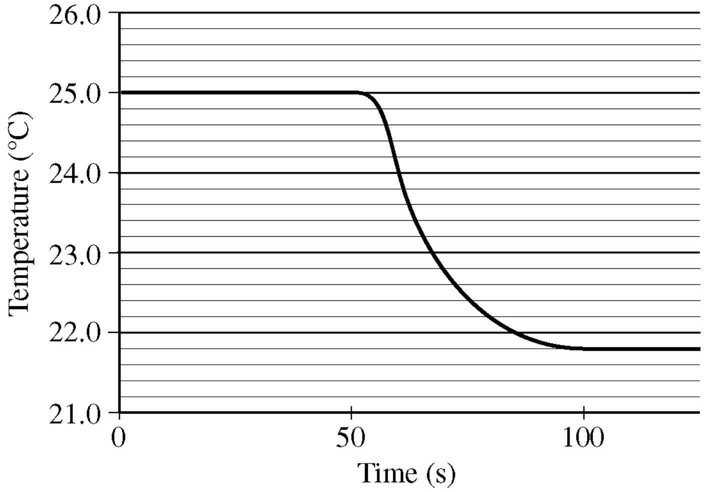
2. A student performs an experiment to determine the molar enthalpy of solution of urea, H_2NCONH_2. The student places 91.95 g of water at 25°C into a coffee-cup calorimeter and immerses a thermometer in the water. After 50 s, the student adds 5.13 g of solid urea, also at 25°C, to the water and measures the temperature of the solution as the urea dissolves. A plot of the temperature data is shown in the graph below.



(a) Determine the change in temperature of the solution that results from the dissolution of the urea.

(b) According to the data, is the dissolution of urea in water an endothermic process or an exothermic process? Justify your answer.

(c) Assume that the specific heat capacity of the calorimeter is negligible and that the specific heat capacity of the solution of urea and water is $4.2 \text{ J g}^{-1} \, ^{\circ}\text{C}^{-1}$ throughout the experiment.

(i) Calculate the heat of dissolution of the urea in joules.

(ii) Calculate the molar enthalpy of solution, ΔH°_{soln}, of urea in kJ mol^{-1}.

(d) Using the information in the table below, calculate the value of the molar entropy of solution, ΔS°_{soln}, of urea at 298 K. Include units with your answer.

	Accepted Value
ΔH°_{soln} of urea	14.0 kJ mol^{-1}
ΔG°_{soln} of urea	-6.9 kJ mol^{-1}

(e) The student repeats the experiment and this time obtains a result for ΔH°_{soln} of urea that is 11 percent below the accepted value. Calculate the value of ΔH°_{soln} that the student obtained in this second trial.

(f) The student performs a third trial of the experiment but this time adds urea that has been taken directly from a refrigerator at 5°C. What effect, if any, would using the cold urea instead of urea at 25°C have on the experimentally obtained value of ΔH°_{soln}? Justify your answer.

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$$8\ H^+(aq) + 4\ Cl^-(aq) + MnO_4^-(aq) \rightarrow 2\ Cl_2(g) + Mn^{3+}(aq) + 4\ H_2O(l)$$

3. $Cl_2(g)$ can be generated in the laboratory by reacting potassium permanganate with an acidified solution of sodium chloride. The net-ionic equation for the reaction is given above.

(a) A 25.00 mL sample of 0.250 M NaCl reacts completely with excess $KMnO_4(aq)$. The $Cl_2(g)$ produced is dried and stored in a sealed container. At 22°C the pressure of the $Cl_2(g)$ in the container is 0.950 atm.

(i) Calculate the number of moles of $Cl^-(aq)$ present before any reaction occurs.

(ii) Calculate the volume, in L, of the $Cl_2(g)$ in the sealed container.

An initial-rate study was performed on the reaction system. Data for the experiment are given in the table below.

Trial	$[Cl^-]$	$[MnO_4^-]$	$[H^+]$	Rate of Disappearance of MnO_4^- in $M\ s^{-1}$
1	0.0104	0.00400	3.00	2.25×10^{-8}
2	0.0312	0.00400	3.00	2.03×10^{-7}
3	0.0312	0.00200	3.00	1.02×10^{-7}

(b) Using the information in the table, determine the order of the reaction with respect to each of the following. Justify your answers.

(i) Cl^-

(ii) MnO_4^-

(c) The reaction is known to be third order with respect to H^+. Using this information and your answers to part (b) above, complete both of the following:

(i) Write the rate law for the reaction.

(ii) Calculate the value of the rate constant, k, for the reaction, including appropriate units.

(d) Is it likely that the reaction occurs in a single elementary step? Justify your answer.

S T O P

If you finish before time is called, you may check your work on this part only.
Do not turn to the other part of the test until you are told to do so.

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CHEMISTRY

Part B

Time—40 minutes

NO CALCULATORS MAY BE USED FOR PART B.

Answer Question 4 below. The Section II score weighting for this question is 10 percent.

4. For each of the following three reactions, write a balanced equation for the reaction in part (i) and answer the question about the reaction in part (ii). In part (i), coefficients should be in terms of lowest whole numbers. Assume that solutions are aqueous unless otherwise indicated. Represent substances in solutions as ions if the substances are extensively ionized. Omit formulas for any ions or molecules that are unchanged by the reaction. You may use the empty space at the bottom of the next page for scratch work, but only equations that are written in the answer boxes provided will be scored.

<u>EXAMPLE:</u>

A strip of magnesium metal is added to a solution of silver(I) nitrate.

(i) Balanced equation:

$Mg + 2\,Ag^{+} \longrightarrow Mg^{2+} + 2\,Ag$

(ii) Which substance is oxidized in the reaction?

Mg is oxidized.

(a) A 0.2 *M* potassium hydroxide solution is titrated with a 0.1 *M* nitric acid solution.

(i) Balanced equation:

(ii) What would be observed if the solution was titrated well past the equivalence point using bromthymol blue as the indicator? (Bromthymol blue is yellow in acidic solution and blue in basic solution.)

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(b) Propane is burned completely in excess oxygen gas.

(i) Balanced equation:

(ii) When the products of the reaction are bubbled through distilled water, is the resulting solution neutral, acidic, or basic? Explain.

(c) A solution of hydrogen peroxide is heated, and a gas is produced.

(i) Balanced equation:

(ii) Identify the oxidation state of oxygen in hydrogen peroxide.

YOU MAY USE THE SPACE BELOW FOR SCRATCH WORK, BUT ONLY EQUATIONS THAT ARE WRITTEN IN THE ANSWER BOXES PROVIDED WILL BE SCORED.

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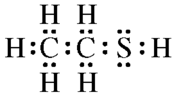
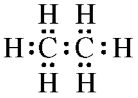
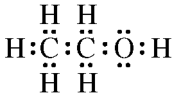
Answer Question 5 and Question 6. The Section II score weighting for these questions is 15 percent each.

Your responses to these questions will be scored on the basis of the accuracy and relevance of the information cited. Explanations should be clear and well organized. Examples and equations may be included in your responses where appropriate. Specific answers are preferable to broad, diffuse responses.

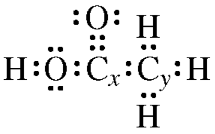
5. Use the information in the table below to respond to the statements and questions that follow. Your answers should be in terms of principles of molecular structure and intermolecular forces.

Compound	Formula	Lewis Electron-Dot Diagram
Ethanethiol	CH_3CH_2SH	 $\mathrm{H{:}\overset{H}{\underset{H}{C}}{:}\overset{H}{\underset{H}{C}}{:}\overset{..}{\underset{..}{S}}{:}H}$
Ethane	CH_3CH_3	 $\mathrm{H{:}\overset{H}{\underset{H}{C}}{:}\overset{H}{\underset{H}{C}}{:}H}$
Ethanol	CH_3CH_2OH	 $\mathrm{H{:}\overset{H}{\underset{H}{C}}{:}\overset{H}{\underset{H}{C}}{:}\overset{..}{\underset{..}{O}}{:}H}$
Ethyne	C_2H_2	

(a) Draw the complete Lewis electron-dot diagram for ethyne in the appropriate cell in the table above.

(b) Which of the four molecules contains the shortest carbon-to-carbon bond? Explain.

(c) A Lewis electron-dot diagram of a molecule of ethanoic acid is given below. The carbon atoms in the molecule are labeled *x* and *y*, respectively.



$$\mathrm{H{:}\overset{..}{\underset{..}{O}}{:}\overset{:\ddot{O}:}{\overset{::}{C_x}}{:}\overset{H}{\underset{H}{C_y}}{:}H}$$

Identify the geometry of the arrangement of atoms bonded to each of the following.

(i) Carbon *x*

(ii) Carbon *y*

(d) Energy is required to boil ethanol. Consider the statement “As ethanol boils, energy goes into breaking C−C bonds, C−H bonds, C−O bonds, and O−H bonds.” Is the statement true or false? Justify your answer.

(e) Identify a compound from the table above that is nonpolar. Justify your answer.

(f) Ethanol is completely soluble in water, whereas ethanethiol has limited solubility in water. Account for the difference in solubilities between the two compounds in terms of intermolecular forces.

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$$2\ \mathrm{Al}(s) + 3\ \mathrm{Zn}^{2+}(aq) \rightarrow 2\ \mathrm{Al}^{3+}(aq) + 3\ \mathrm{Zn}(s)$$

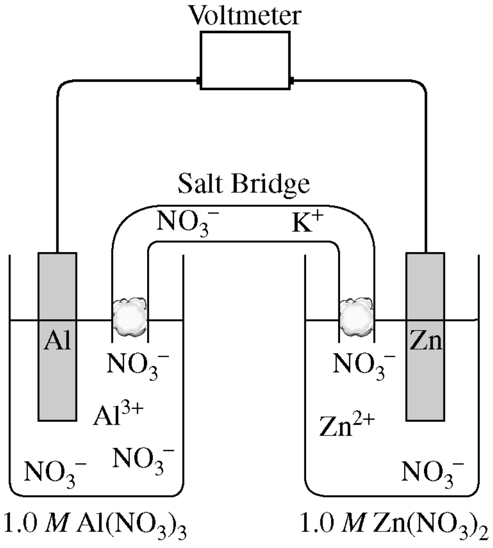
6. Respond to the following statements and questions that relate to the species and the reaction represented above.

   (a) Write the complete electron configuration (e.g., $1s^2\,2s^2 \ldots$) for Zn^{2+}.

   (b) Which species, Zn or Zn^{2+}, has the greater ionization energy? Justify your answer.

   (c) Identify the species that is oxidized in the reaction.

   The diagram below shows a galvanic cell based on the reaction. Assume that the temperature is 25°C.



   (d) The diagram includes a salt bridge that is filled with a saturated solution of $\mathrm{KNO_3}$. Describe what happens in the salt bridge as the cell operates.

   (e) Determine the value of the standard voltage, $E°$, for the cell.

   (f) Indicate whether the value of the standard free-energy change, $\Delta G°$, for the cell reaction is positive, negative, or zero. Justify your answer.

   (g) If the concentration of $\mathrm{Al(NO_3)_3}$ in the $\mathrm{Al}(s)/\mathrm{Al}^{3+}(aq)$ half-cell is lowered from 1.0 M to 0.01 M at 25°C, does the cell voltage increase, decrease, or remain the same? Justify your answer.

STOP

END OF EXAM

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