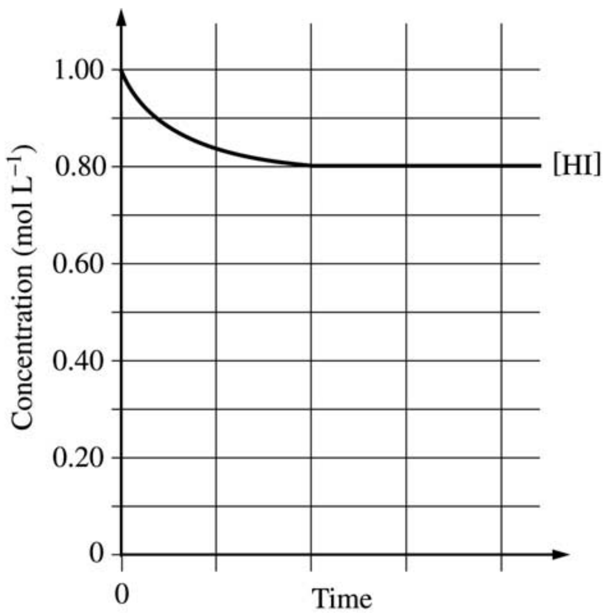
AP® Chemistry
2003 Scoring Guidelines
Form B

Question 1

Total Score 10 points

$$2\ HI(g) \leftrightarrow H_2(g) + I_2(g)$$

1. After a 1.0 mole sample of HI(g) is placed into an evacuated 1.0 L container at 700. K, the reaction represented above occurs. The concentration of HI(g) as a function of time is shown below.



(a) Write the expression for the equilibrium constant, K_c, for the reaction.

$K_c = \dfrac{[H_2][I_2]}{[HI]^2}$	1 point for correct expression

(b) What is [HI] at equilibrium?

From the graph, $[HI]_{eq}$ is 0.80 M	1 point for equilibrium [HI]

Question 1 (cont'd.)

(c) Determine the equilibrium concentrations of $H_2(g)$ and $I_2(g)$.

$2\ HI(g) \rightarrow H_2(g) + I_2(g)$ I: 1.0 *M*, 0, 0 C: −0.20 *M*, +0.10 *M*, +0.10 *M* E: 0.80 *M*, 0.10 *M*, 0.10 *M* $[I_2] = [H_2] = 0.10\ M$	1 point for stoichiometric relationship between HI reacting and $H_2(g)$ or $I_2(g)$ forming 1 point for $[H_2]_{eq}$ and $[I_2]_{eq}$

(d) On the graph above, make a sketch that shows how the concentration of $H_2(g)$ changes as a function of time.

From the graph, $[H_2]_{eq}$ is 0.10 *M* The curve should have the following characteristics: - start at 0 *M*; - increase to 0.1 *M*; - reach equilibrium at the same time [HI] reaches equilibrium	1 point for any two characteristics 2 points for all three characteristics

(e) Calculate the value of the following equilibrium constants for the reaction at 700. K.

(i) K_c

$K_c = \frac{[H_2][I_2]}{[HI]^2} = \frac{[0.10][0.10]}{[0.80]^2} = 0.016$	1 point for correct substitution (must agree with parts (b) and (c))

(ii) K_p

$K_p = K_c = 0.016$ The number of moles on the product side is equal to the number of moles on the reactant side $K_p = K_c(RT)^{\Delta n}$ $\Delta n = 2 - 2 = 0$ $K_p = K_c(RT)^0$ $K_p = K_c$	1 point for $K_p = K_c$ (with verification)

Question 1 (cont'd.)

(f) At 1,000 K, the value of K_c for the reaction is 2.6×10^{-2}. In an experiment, 0.75 mole of HI(*g*), 0.10 mole of $H_2(g)$, and 0.50 mol of $I_2(g)$ are placed in a 1.0 L container and allowed to reach equilibrium at 1,000 K. Determine whether the equilibrium concentration of HI(*g*) will be greater than, equal to, or less than the initial concentration of HI(*g*). Justify your answer.

$Q = \frac{[H_2][I_2]}{[HI]^2} = \frac{[0.10][0.50]}{[0.75]^2} = 8.9 \times 10^{-2}$ $K_c = 2.6 \times 10^{-2}$ $Q > K_c$ To establish equilibrium, the numerator must decrease and the denominator must increase. Therefore, [HI] will increase.	1 point for calculating Q and comparing to K_c 1 point for predicting correct change in [HI]

Question 2

Total Score 10 points

2. Answer the following questions that relate to chemical reactions.

   (a) Iron(III) oxide can be reduced with carbon monoxide according to the following equation.

$$Fe_2O_3(s) + 3\ CO(g) \rightarrow 2\ Fe(s) + 3\ CO_2(g)$$

A 16.2 L sample of $CO(g)$ at 1.50 atm and 200.°C is combined with 15.39 g of $Fe_2O_3(s)$.

(i) How many moles of $CO(g)$ are available for the reaction?

$PV = nRT$ $n_{CO} = \frac{PV}{RT} = \frac{(1.50\text{ atm})(16.2\text{ L})}{0.0821 \frac{\text{L·atm}}{\text{mol·K}}(473\text{ K})} = 0.626\text{ mol CO}$	1 point for correct substitution 1 point for answer

(ii) What is the limiting reactant for the reaction? Justify your answer with calculations.

$n_{Fe_2O_3} = 15.39\text{ g }Fe_2O_3\left(\frac{1\text{ mol }Fe_2O_3}{159.7\text{ g }Fe_2O_3}\right) = 0.0964\text{ mol }Fe_2O_3$ $n_{CO\text{ required}} = 0.0964\text{ mol }Fe_2O_3\left(\frac{3\text{ mol CO}}{1\text{ mol }Fe_2O_3}\right) = 0.289\text{ mol}$ CO required to completely react with 0.0964 mol Fe_2O_3 0.626 mol CO are available, so CO is in excess and Fe_2O_3 is limiting. OR $n_{Fe_2O_3\text{ required}} = 0.626\text{ mol CO}\left(\frac{1\text{ mol }Fe_2O_3}{3\text{ mol CO}}\right) = 0.209\text{ mol}$ 0.209 mol Fe_2O_3 corresponds to 33.4 g Fe_2O_3 (the amount of Fe_2O_3 required to completely react with 0.626 mol CO) 0.0964 mol of Fe_2O_3 is available, so there is not enough Fe_2O_3 to completely react with 0.626 mol CO. Therefore, Fe_2O_3 is the limiting reactant.	1 point for moles of CO or Fe_2O_3 required 1 point for correct conclusion <u>NOTE:</u> Answer must be consistent with moles of CO calculated in part (a)

Question 2 (cont'd.)

(iii) How many moles of Fe(*s*) are formed in the reaction?

$n_{Fe} = 0.0964 \text{ mol } Fe_2O_3 \left(\frac{2 \text{ mol Fe}}{1 \text{ mol } Fe_2O_3}\right) = 0.193 \text{ mol Fe produced}$ If 0.626 mol CO is used as the limiting reactant, then the number of moles of Fe formed is: $n_{Fe} = 0.626 \text{ mol CO} \left(\frac{2 \text{ mol Fe}}{3 \text{ mol CO}}\right) = 0.417 \text{ mol Fe}$	1 point for correct number of moles of Fe formed <u>Note:</u> Values must be consistent with answer in part (a) (ii).

(b) In a reaction vessel, 0.600 mol of $Ba(NO_3)_2(s)$ and 0.300 mol of $H_3PO_4(aq)$ are combined with deionized water to a final volume of 2.00 L. The reaction represented below occurs.

$$3\ Ba(NO_3)_2(aq) + 2\ H_3PO_4(aq) \rightarrow Ba_3(PO_4)_2(s) + 6\ HNO_3(aq)$$

(i) Calculate the mass of $Ba_3(PO_4)_2(s)$ formed.

$n_{H_3PO_4} = 0.600 \text{ mol } Ba(NO_3)_2 \left(\frac{2 \text{ mol } H_3PO_4}{3 \text{ mol } Ba(NO_3)_2}\right) = 0.400 \text{mol } H_3PO_4$ required to completely react with 0.600 mol $Ba(NO_3)_2$. There is 0.300 mol H_3PO_4 available. Therefore, H_3PO_4 is the limiting reactant. $\text{mass}_{Ba_3(PO_4)_2} = 0.300 \text{ mol } H_3PO_4 \left(\frac{1 \text{ mol } Ba_3(PO_4)_2}{2 \text{ mol } H_3PO_4}\right) \times$ $\left(\frac{602 \text{ g } Ba_3(PO_4)_2}{1 \text{ mol } Ba_3(PO_4)_2}\right) = 90.3 \text{ g } Ba_3(PO_4)_2$ If $Ba(NO_3)_2$ is used as the limiting reactant: $\text{mass}_{Ba_3(PO_4)_2} = 0.600 \text{ mol } Ba(NO_3)_2 \left(\frac{1 \text{ mol } Ba_3(PO_4)_2}{3 \text{ mol } Ba(NO_3)_2}\right)$ $\left(\frac{602 \text{ g } Ba_3(PO_4)_2}{1 \text{ mol } Ba_3(PO_4)_2}\right) = 120. \text{ g } Ba_3(PO_4)_2$	1 point for determining the limiting reactant 1 point for determining the correct mass of $Ba_3(PO_4)_2$

Question 2 (cont'd.)

(ii) Calculate the pH of the resulting solution.

$n_{HNO_3} = 0.300 \text{ mol } H_3PO_4 \left(\frac{6 \text{ mol } HNO_3}{2 \text{ mol } H_3PO_4}\right) = 0.900 \text{ mol } HNO_3$ $[HNO_3] = \frac{0.900 \text{ mol } HNO_3}{2.0 \text{ L}} = 0.45\ M$ Since all the H_3PO_4 has reacted, the only acid in the solution is HNO_3. Since HNO_3 is a strong acid it completely dissociates. $pH = -\log[H^+] = -\log(0.45) = 0.35$ If $Ba(NO_3)_2$ is used as the limiting reactant $n_{HNO_3} = 0.600 \text{ mol } Ba(NO_3)_2 \left(\frac{6 \text{ mol } HNO_3}{3 \text{ mol } Ba(NO_3)_2}\right) = 1.2 \text{ mol } HNO_3$ $[HNO_3] = \frac{1.2 \text{ mol } HNO_3}{2.0 \text{ L}} = 0.60\ M$ $pH = -\log[H^+] = -\log(0.60) = 0.22$	1 point for number of moles of H^+ 1 point for calculation of $[H^+]$ and pH Must be consistent with part (b) (i)

(iii) What is the concentration, in mol L^{-1}, of the nitrate ion, $NO_3^-(aq)$, after the reaction reaches completion?

The final concentration of NO_3^- must be the same as the initial concentration. $n_{NO_3^-} = 0.600 \text{ mol } Ba(NO_3)_2 \left(\frac{2 \text{ mol } NO_3^-}{1 \text{ mol } Ba(NO_3)_2}\right) = 1.2 \text{ mol } NO_3^-$ $[NO_3^-] = \frac{1.2 \text{ mol } NO_3^-}{2.0 \text{ L}} = 0.60\ M\ NO_3^-$	1 point for concentration of NO_3^-

Question 3

Total Score 10 points

3. In an experiment, a sample of an unknown, pure gaseous hydrocarbon was analyzed. Results showed that the sample contained 6.000 g of carbon and 1.344 g of hydrogen.

(a) Determine the empirical formula of the hydrocarbon.

$n_C = 6.000 \text{ g C}\left(\frac{1 \text{ mol C}}{12.00 \text{ g C}}\right) = 0.5000 \text{ mol C}$ $n_H = 1.344 \text{ g H}\left(\frac{1 \text{ mol H}}{1.008 \text{ g H}}\right) = 1.333 \text{ mol H}$	1 point for number of moles of carbon and number of moles of hydrogen
$\frac{0.5000 \text{ mol C}}{0.5000} : \frac{1.333 \text{ mol H}}{0.5000}$ 1 mol C : 2.667 mol H	1 point for ratio of moles of carbon to moles of hydrogen
3 (1 mol C : 2.667 mol H) = 3 mol C : 8.000 mol H The empirical formula is C_3H_8	1 point for correct formula

(b) The density of the hydrocarbon at 25°C and 1.09 atm is 1.96 g L^{-1}.

(i) Calculate the molar mass of the hydrocarbon.

$PV = nRT$ $PV = \frac{\text{grams}}{\text{molar mass}} RT$ $\text{molar mass} = \frac{\text{grams}}{V}\frac{RT}{P}$ $\text{molar mass} = 1.96 \text{ g L}^{-1} \frac{0.0821 \frac{\text{L}\cdot\text{atm}}{\text{mol}\cdot\text{K}} 298 \text{ K}}{1.09 \text{ atm}}$ $\text{molar mass} = 44.0 \text{ g mol}^{-1}$ $1.96 \text{ g L}^{-1} \times 22.4 \text{ L mol}^{-1} = 43.9 \text{ g mol}^{-1}$ (1 point maximum)	1 point for correct substitution and 1 point for answer OR 1 point for calculation and 1 point for units

(ii) Determine the molecular formula of the hydrocarbon.

Empirical mass × n = molar mass Empirical mass for C_3H_8 is 44 g mol^{-1} 44 g mol^{-1} × n = 44 g mol^{-1} ⇒ n = 1, so the molecular formula is the same as the empirical formula, C_3H_8	1 point for reporting correct formula with verification

Question 3 (cont'd.)

In another experiment, liquid heptane, $C_7H_{16}(l)$, is completely combusted to produce $CO_2(g)$ and $H_2O(l)$, as represented by the following equation.

$$C_7H_{16}(l) + 11\ O_2(g) \rightarrow 7\ CO_2(g) + 8\ H_2O(l)$$

The heat of combustion, ΔH°_{comb}, for one mole of $C_7H_{16}(l)$ is -4.85×10^3 kJ.

(c) Using the information in the table below, calculate the value of ΔH°_f for $C_7H_{16}(l)$ in kJ mol^{-1}.

Compound	ΔH°_f (kJ mol^{-1})
$CO_2(g)$	−393.5
$H_2O(l)$	−285.8

$\Delta H^\circ_f = \sum \Delta H^\circ_f \text{ (products)} - \sum \Delta H^\circ_f \text{ (reactants)}$ $= 7\ \Delta H^\circ_f (CO_2) + 8\ \Delta H^\circ_f (H_2O) - [\Delta H^\circ_f (C_7H_{16}) + 11\ \Delta H^\circ_f (O_2)]$ $-4{,}850 \frac{kJ}{mol} = 7(-393.5 \frac{kJ}{mol}) + 8(-285.8 \frac{kJ}{mol}) - [\Delta H^\circ_f (C_7H_{16}) + 11 (0 \frac{kJ}{mol})]$ $-4{,}850 \frac{kJ}{mol} = -2{,}754 \frac{kJ}{mol} - 2{,}286 \frac{kJ}{mol} - \Delta H^\circ_f (C_7H_{16})$ $\Delta H^\circ_f (C_7H_{16}) = -191 \frac{kJ}{mol}$	1 point for correct coefficients 1 point for the correct substitution into ΔH°_f equation

(d) A 0.0108 mol sample of $C_7H_{16}(l)$ is combusted in a bomb calorimeter.

(i) Calculate the amount of heat released to the calorimeter.

$q_{\text{released}} = 0.0108 \text{ mol } C_7H_{16} \left(\frac{-4850 \text{ kJ}}{1 \text{ mol } C_7H_{16}}\right)$ $= 52.4$ kJ of heat released	1 point for the amount of heat released

(ii) Given that the total heat capacity of the calorimeter is 9.273 kJ °C^{-1}, calculate the temperature change of the calorimeter.

$Q = C_p \Delta T$ $52.4 \text{ kJ} = 9.273 \text{ kJ °C}^{-1} \times \Delta T$ $\Delta T = \left(\frac{52.4 \text{ kJ}}{9.273 \text{ kJ °C}^{-1}}\right) = 5.65\text{°C}$ $\Delta T = -(-52.4 \text{ kJ})/(9.273 \text{ kJ })\text{°C}^{-1} = +5.65\text{°C}$	1 point for the correct change in temperature (Must be consistent with answer in part (d)(i))

Question 4

Total Score 15 points

4. (a) Hot hydrogen gas is passed over heated copper(II) oxide solid.

$$H_2 + CuO \rightarrow Cu + H_2O$$

<u>Note:</u> *Cu_2O is an acceptable product*

(b) Solid sodium hydride is added to water.

$$NaH + H_2O \rightarrow Na^+ + OH^- + H_2$$

(c) Propanone is burned in air.

$$C_3H_6O + O_2 \rightarrow CO_2 + H_2O$$

<u>Note:</u> *CO is an acceptable product*

(d) A solution of lead(II) nitrate is added to a solution of potassium sulfate.

$$Pb^{2+} + SO_4^{2-} \rightarrow PbSO_4$$

(e) Ammonia gas is mixed with hydrogen chloride gas.

$$HCl + NH_3 \rightarrow NH_4Cl$$

<u>Note:</u> *1 product point for $NH_4^+ + Cl^-$; 2 points (total) for $NH_3 + H^+ \rightarrow NH_4^+$*

(f) Sulfur trioxide gas is bubbled into water.

$$SO_3 + H_2O \rightarrow H^+ + HSO_4^-$$

(g) Excess concentrated potassium hydroxide solution is added to a solution of nickel(II) chloride.

$$OH^- + Ni^{2+} \rightarrow Ni(OH)_4^{2-}$$

<u>Note:</u> *$Ni(OH)_2$, $Ni(OH)_3^-$, $Ni(OH)_5^{3-}$, and $Ni(OH)_6^{4-}$ are acceptable products*

(h) Solid sodium acetate is added to 1.0 *M* hydrobromic acid.

$$NaC_2H_3O_2 + H^+ \rightarrow HC_2H_3O_2 + Na^+$$

Question 5

Total Score 10 points

5. Oxalic acid, $H_2C_2O_4$, is a primary standard used to determine the concentration of potassium permanganate, $KMnO_4$, in solution. The equation for the reaction is as follows.

$$2\ KMnO_4(aq) + 5\ H_2C_2O_4(aq) + 3\ H_2SO_4 \rightarrow 2\ MnSO_4(aq) + 10\ CO_2(g) + 8\ H_2O(l) + K_2SO_4(aq)$$

A student dissolves a sample of oxalic acid in a flask with 30 mL of water and 2.00 mL of 3.00 M H_2SO_4. The $KMnO_4$ solution of unknown concentration is in a 25.0 mL buret. In the titration, the $KMnO_4$ solution is added to the solution containing the oxalic acid.

(a) What chemical species is being oxidized in the reaction?

$H_2C_2O_4$ is the substance being oxidized. The half-reaction is: $H_2C_2O_4(aq) \rightarrow 2\ CO_2(g) + 2\ H^+(aq) + 2\ e^-$ ***OR*** The oxidation state of carbon changes from +3 to +4 in CO_2.	1 point for identifying $H_2C_2O_4$ or $C_2O_4^{2-}$ as species oxidized

(b) What substance indicates the observable endpoint of the titration? Describe the observation that shows the endpoint has been reached.

In the reaction, the purple $KMnO_4$ solution in the buret is added to the colorless solution in the flask. $KMnO_4$ reacts with $H_2C_2O_4$ upon addition, so the purple $KMnO_4$ color disappears as it is added to the solution in the flask that contains unreacted $H_2C_2O_4$.	1 point for identifying $KMnO_4$ as reacting species that indicates the endpoint
As soon as all the $H_2C_2O_4$ has reacted (endpoint), the $KMnO_4$ is in excess and the solution in the flask will turn pink (pink is the color produced when the more concentrated purple $KMnO_4$ solution in the buret is diluted in the solution in the flask).	1 point for indicating color change is from colorless to pink at the endpoint

(c) What data must be collected in the titration in order to determine the molar concentration of the unknown $KMnO_4$ solution?

The mass of oxalic acid, the initial volume of the $KMnO_4$ solution in the buret, and the final volume of the $KMnO_4$ solution in the buret	1 point for the mass of oxalic acid 1 point for the initial and final volume *or* for saying the change in volume of $KMnO_4$

Question 5 (cont'd.)

(d) Without doing any calculations, explain how to determine the molarity of the unknown $KMnO_4$ solution.

Determine the moles of oxalic acid (by dividing the mass of oxalic acid measured/weighed, by the molar mass of oxalic acid).	1 point for determining moles of $H_2C_2O_4$
Use the stoichiometric ratio of the amount (2 mol) of $KMnO_4$ to amount (5 mol) of $H_2C_2O_4$ from the balanced chemical equation to convert from amount (in moles) of $H_2C_2O_4$ to amount (in moles) of $KMnO_4$.	1 point for using correct stoichiometric factor
Divide the amount (in moles) of $KMnO_4$ by the volume, expressed in liters, of $KMnO_4$ needed to reach the endpoint.	1 point for dividing moles of $KMnO_4$ by liters of $KMnO_4$ solution

(e) How would the calculated concentration of the $KMnO_4$ solution be affected if 40 mL of water was added to the oxalic acid initially instead of 30 mL? Explain your reasoning.

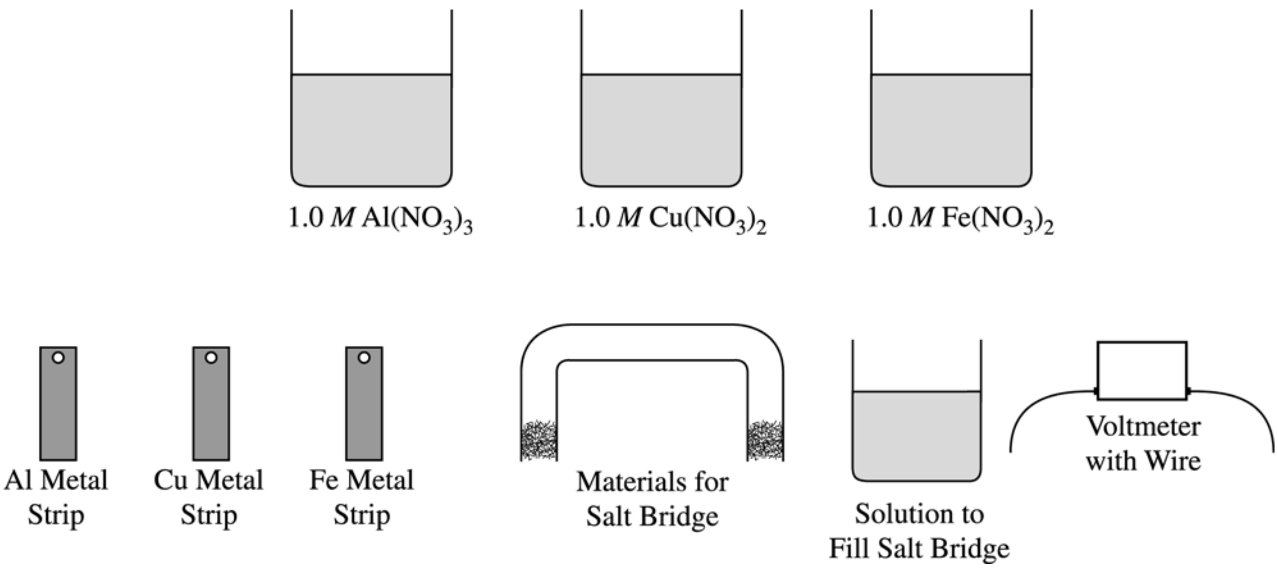
There would be no effect on the concentration of the $KMnO_4$ solution. We are only interested in the moles of oxalic acid. Since it is a solid, the moles of oxalic acid are calculated from the mass of oxalic acid. The volume of water used to dissolve the oxalic acid is independent of the moles of oxalic acid.	1 point for effect 1 point for explanation

Question 6

Total Score 9 points

6. Answer the following questions about electrochemistry.

(a) Several different electrochemical cells can be constructed using the materials shown below. Write the balanced net-ionic equation for the reaction that occurs in the cell that would have the greatest positive value of E°_{cell} .



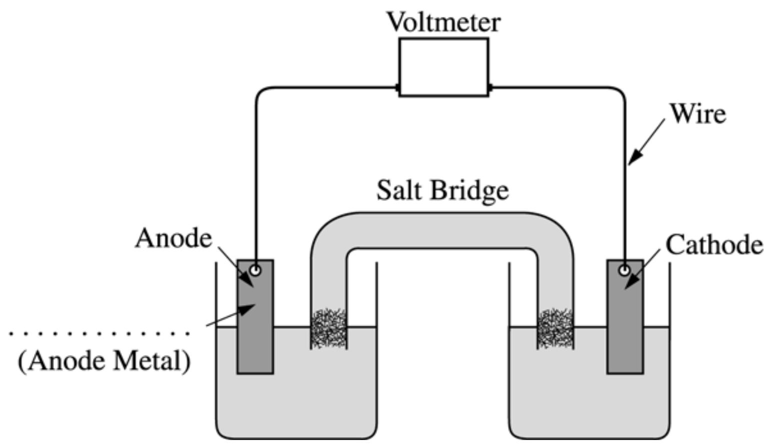
$Al(s) \rightarrow Al^{3+}(aq) + 3\,e^-$ $Cu^{2+}(aq) + 2\,e^- \rightarrow Cu(s)$ $2\,Al(s) + 3\,Cu^{2+}(aq) \rightarrow 2\,Al^{3+}(aq) + 3\,Cu(s)$	1 point for selection of correct two redox couples 1 point for correctly balanced net ionic equation

(b) Calculate the standard cell potential, E°_{cell} , for the reaction written in part (a).

$Al^{3+}(aq) + 3\,e^- \rightarrow Al(s)$ $E^\circ = -1.66$ V $Cu^{2+}(aq) + 2\,e^- \rightarrow Cu(s)$ $E^\circ = +0.34$ V $E^\circ_{cell} = E^\circ_{cathode} - E^\circ_{anode} = +0.34\text{ V} - (-1.66\text{ V}) = +2.00\text{ V}$	1 point for correct E°_{cell} (Must be consistent with part (a))

Question 6 (cont'd.)

(c) A cell is constructed based on the reaction in part (a) above. Label the metal used for the anode on the cell shown in the figure below.



The metal is aluminum solid.	1 point for correct metal (Must be consistent with part (a))

(d) Of the compounds NaOH, CuS, and $NaNO_3$, which one is appropriate to use in a salt bridge? Briefly explain your answer, and for each of the other compounds, include a reason why it is not appropriate.

NaOH is not appropriate. The anion, OH^-, would migrate towards the anode. The OH^- would react with the Al^{3+} ion in solution. CuS is not appropriate. It is insoluble in water, so no ions would be available to migrate to the anode and cathode compartment to balance the charge. $NaNO_3$ is appropriate. It is soluble in water, and neither the cation nor the anion will react with the ions in the anode or cathode compartment.	1 point for correctly indicating whether each compound is appropriate, along with an explanation (3 points total)

Question 6 (cont'd.)

(e) Another standard cell is based on the following reaction.

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

If the concentration of Zn^{2+} is decreased from 1.0 M to 0.25 M, what effect does this have on the cell potential? Justify your answer.

$E_{cell} = E^{\circ}_{cell} - 0.059 \ln\left(\frac{[Zn^{2+}]}{[Pb^{2+}]}\right)$ If $[Zn^{2+}]$ is reduced, then the ratio $\left(\frac{[Zn^{2+}]}{[Pb^{2+}]}\right) < 1$, therefore $\ln\left(\frac{[Zn^{2+}]}{[Pb^{2+}]}\right) < 0$. Thus E_{cell} increases (becomes more positive).	1 point for correctly indicating how E_{cell} is affected 1 point for explanation in terms of Nernst equation and Q

Question 7

Total Score 8 points

7. Account for the following observations using principles of atomic structure and/or chemical bonding. In each part, your answer must include specific information about both substances.

(a) The Ca^{2+} and Cl^{-} ions are isoelectronic, but their radii are not the same. Which ion has the larger radius? Explain.

Both Ca^{2+} and Cl^{-} ions have 18 electrons. Their electron configuration is $1s^22s^22p^63s^23p^6$. However, they differ by the number of protons in the nucleus. Calcium has 20 protons and chlorine has 17 protons.	1 point for indicating that chloride ion has the larger ionic radius
The valence electrons are shielded by the same number of electrons in each ion (10), so the effective nuclear charge (ENC) experienced by the valence electrons in Ca^{2+} is +10 and for Cl^{-} the ENC is +7. The valence electrons in Cl^{-} experience a smaller attraction to the nucleus due to the smaller nuclear charge, so Cl^{-} has the larger ionic radius. (The same argument is acceptable when comparing the total number of protons versus total number of electrons for each ion.)	1 point for correct explanation

(b) Carbon and lead are in the same group of elements, but carbon is classified as a nonmetal and lead is classified as a metal.

Binary compounds of carbon exhibit covalent character (property of a nonmetallic element), whereas binary compounds of lead exhibit ionic character (property of a metallic element). OR Oxides of carbon, when dissolved in water, are acidic (property of a nonmetallic element), whereas oxides of lead, when added to water, are basic (property of a metallic element). OR Carbon is a poor thermal conductor (property of a nonmetallic element), whereas lead is a very good thermal conductor (property of a metallic element). Note: Students may use other examples where the chemical or physical properties of carbon and lead differ to distinguish between the two elements.)	1 point each for indicating the characteristic of each element and the difference in behavior exhibited by the element, and then relating the behavior to a metal or nonmetal

Question 7 (cont'd.)

(c) Compounds containing Kr have been synthesized, but there are no known compounds that contain He.

Helium has a filled shell (the first shell), so does not tend to lose or gain electrons. Therefore, helium does not react. Krypton, while having filled 4*s* and 4*p* sublevels, has empty 4*d* and 4*f* sublevels. These empty orbitals affect the reactivity of Kr. Note: Also acceptable is a comparison of the ionization energies of helium, and krypton and then the justification for krypton being more reactive.	1 point for filled shell for He 1 point for indicating presence of empty *d* orbitals in Kr

(d) The first ionization energy of Be is 900 kJ mol^{-1}, but the first ionization energy of B is 800 kJ mol^{-1}.

The electron configuration for Be is $1s^2 2s^2$, whereas the electron configuration for B is $1s^2 2s^2 2p^1$. The first electron removed in boron is in a 2*p* subshell, which is higher in energy than the 2*s* subshell, from which the first electron is removed in beryllium. The higher in energy the subshell containing the electron to be removed (ionized), the lower the ionization energy.	1 point for indicating the difference in the subshell where the first electron is removed for each element 1 point for associating higher energy sublevel with lower ionization energy

Question 8

Total Score 8 points

8. The decay of the radioisotope I-131 was studied in a laboratory. I-131 is known to decay by beta (${}^{0}_{-1}e$) emission.

(a) Write a balanced nuclear equation for the decay of I-131.

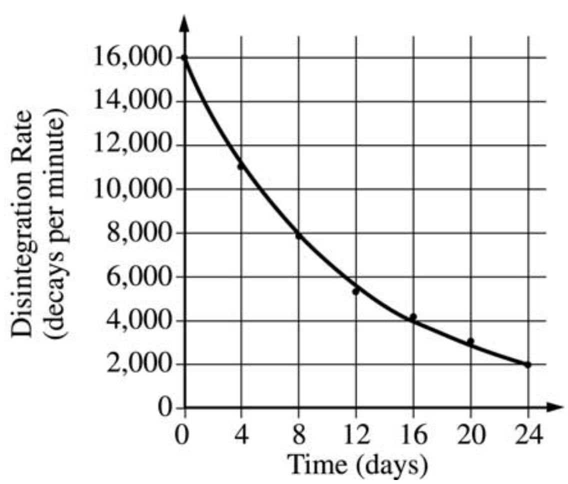
${}^{131}_{53}\text{I} \rightarrow {}^{131}_{54}\text{Xe} + {}^{0}_{-1}e$	1 point for correct equation

Note: "β" for ${}^{0}_{-1}e$ is acceptable

(b) What is the source of the beta particle emitted from the nucleus?

A neutron spontaneously decays to an electron and a proton.	1 point for identifying a neutron as the source of the beta emission

The radioactivity of a sample of I-131 was measured. The data collected are plotted on the graph below.

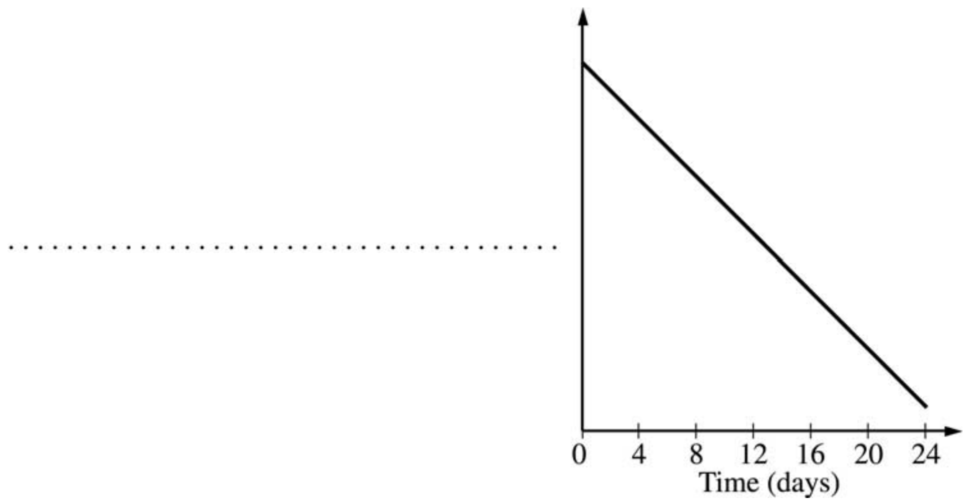


(c) Determine the half-life, $t_{1/2}$, of I-131 using the graph above.

The half-life is 8 days. That is the time required for the disintegration rate to fall from 16,000 to one-half its initial value, 8,000.	1 point for half-life

Question 8 (cont'd.)

(d) The data can be used to show that the decay of I-131 is a first-order reaction, as indicated on the graph below.



(i) Label the vertical axis of the graph above.

The label on the y-axis should be ln or log one of the following: disintegrations or moles or atoms or [I-131] or disintegration rate.	1 point for correct label on y-axis

(ii) What are the units of the rate constant, k, for the decay reaction?

From the graph, the units on the rate constant are days^{-1} (Units of time^{-1} is acceptable)	1 point for correct units

(iii) Explain how the half-life of I-131 can be calculated using the slope of the line plotted on the graph.

The slope of the line is $-k$. The slope is negative, so k is a positive number. The half-life can then be calculated using the relationship $t_{1/2} = \frac{0.693}{k}$.	1 point for indicating slope is k 1 point for half-life equation

(d) Compare the value of the half-life of I-131 at 25°C to its value at 50°C.

The half-life will be the same at the different temperatures. The half-life of a nuclear decay process is independent of temperature.	1 point