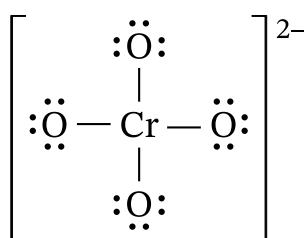


Question 2: Version J

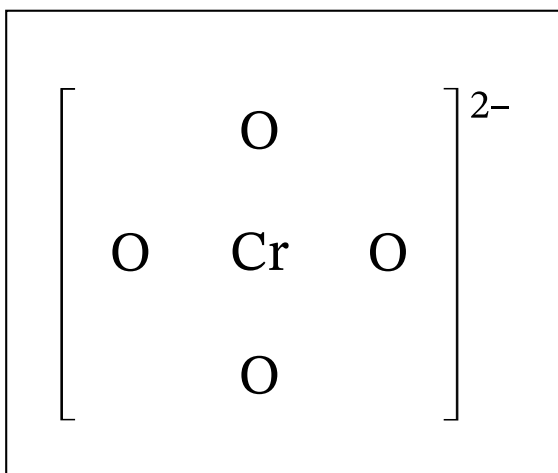
2. Answer the following questions about the chromate ion, CrO_4^{2-} , and the dichromate ion, $\text{Cr}_2\text{O}_7^{2-}$.

Part A

The bonds between chromium and oxygen in CrO_4^{2-} can be represented as covalent bonds. One possible Lewis diagram for the CrO_4^{2-} ion is shown in Figure 1.

Figure 1

- Based on VSEPR theory, **predict** the molecular geometry of the CrO_4^{2-} ion.
- On Figure 2, **draw** a complete Lewis diagram for a resonance structure of CrO_4^{2-} that results in a formal charge of zero on two of the O atoms and a formal charge of -1 on the other two O atoms. Your diagram should contain the same number of valence electrons as in Figure 1.

Figure 2

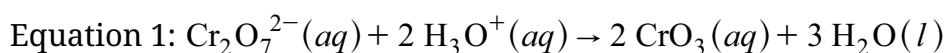
Part B

When reacted with a strong acid like $\text{HNO}_3(aq)$, $\text{CrO}_4^{2-}(aq)$ can be converted to $\text{Cr}_2\text{O}_7^{2-}(aq)$ and $\text{H}_2\text{O}(l)$ in a reversible reaction.

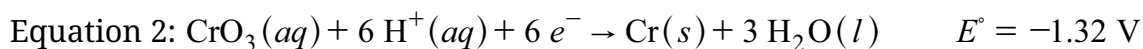
- i. **Write** a balanced net ionic equation for the reaction between $\text{CrO}_4^{2-}(aq)$ and a strong acid.
- ii. Is the reaction a redox reaction? **Justify** your answer based on the oxidation number of Cr.

The following information applies to parts C and D.

In acidic solutions, $\text{Cr}_2\text{O}_7^{2-}(aq)$ reacts to form $\text{CrO}_3(aq)$ according to Equation 1.



$\text{CrO}_3(aq)$ can be electrolyzed to plate objects with a thin layer of chromium metal according to Equation 2.

**Part C**

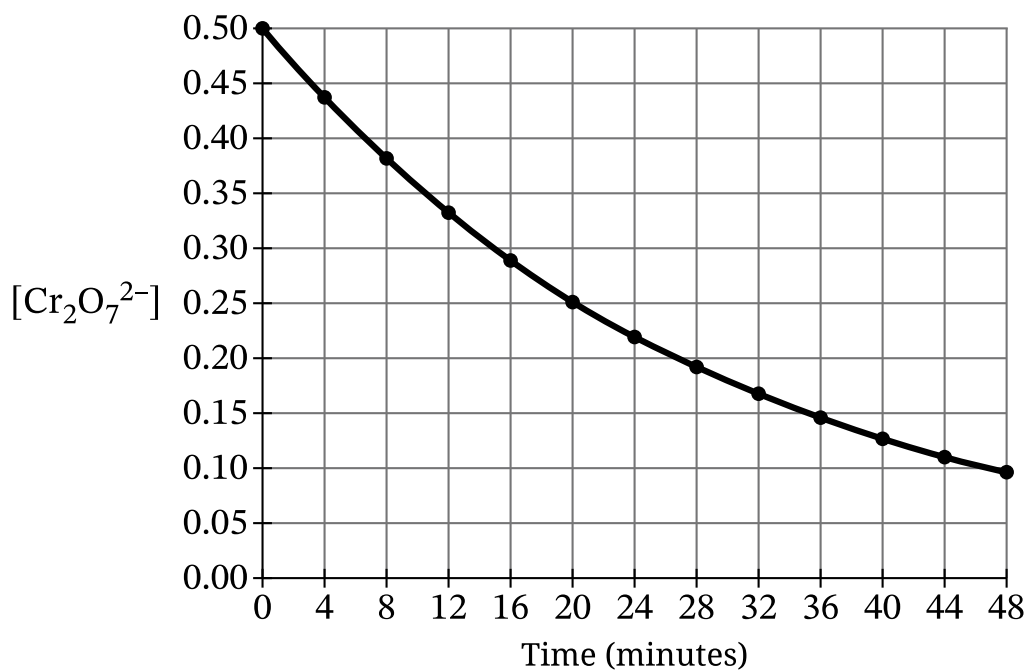
Is the reaction represented by Equation 2 thermodynamically favorable or unfavorable under standard conditions? **Justify** your answer with a calculation of ΔG° . Show the work that leads to your answer.

Part D

Calculate the number of grams of $\text{Cr}(s)$ that could be plated onto the surface of a steel rod when 15.0 A of current is applied for 3250 seconds. Show the work that leads to your answer.

Part E

In a separate experiment, an iron wire is placed directly in a solution of $0.50\text{ M Cr}_2\text{O}_7^{2-}(aq)$ with $\text{pH} = 1.99$. The concentration of $\text{Cr}_2\text{O}_7^{2-}(aq)$ remaining is recorded over time, and the results are presented in Figure 3.

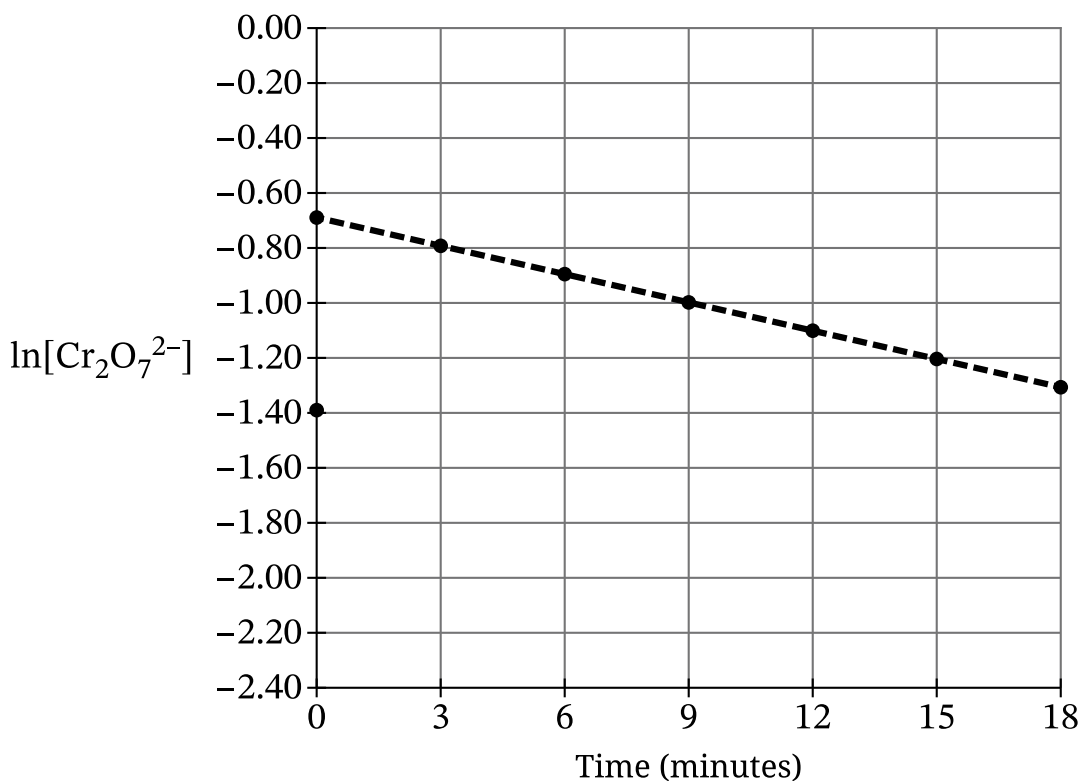
Figure 3

Explain how the data in Figure 3 support the conclusion that the reaction is first order with respect to $\text{Cr}_2\text{O}_7^{2-}$.

The following information applies to parts F and G.

The student creates a plot of $\ln [\text{Cr}_2\text{O}_7^{2-}]$ versus time for a trial with an initial concentration of $0.50\text{ M Cr}_2\text{O}_7^{2-}(\text{aq})$, as shown in Figure 4.

Figure 4



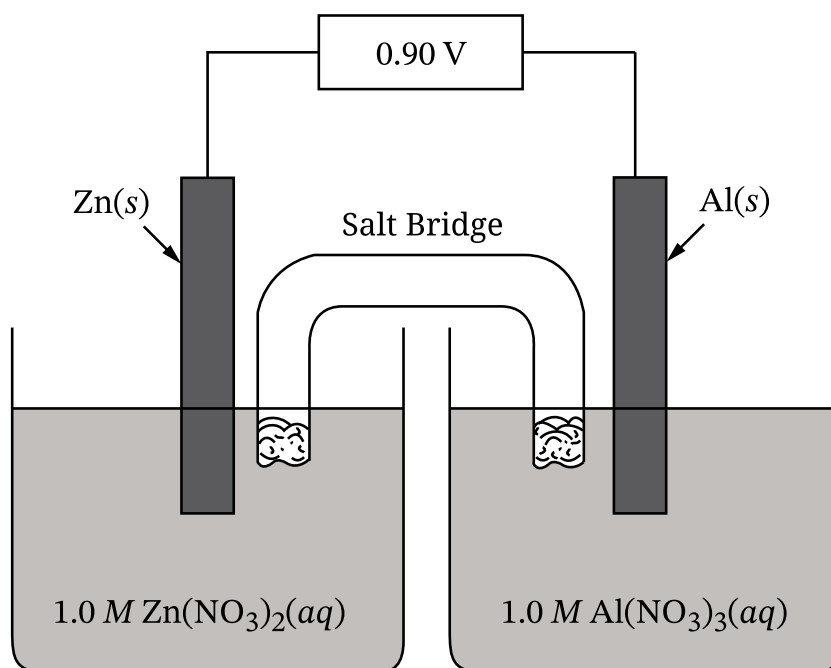
Part F

Calculate the value of the rate constant, k , for the reaction. Report your answer in units of min^{-1} . Show the work that leads to your answer.

Part G

The student then runs a second trial of the experiment under identical conditions but uses an initial concentration of $0.25\text{ M Cr}_2\text{O}_7^{2-}(\text{aq})$ instead of $0.50\text{ M Cr}_2\text{O}_7^{2-}(\text{aq})$. On Figure 4, carefully **draw** the plot of $\ln [\text{Cr}_2\text{O}_7^{2-}]$ versus time that would be expected for the second experiment. The point at time zero has already been plotted.

6. A scientist constructs a galvanic cell as shown in the diagram. As the cell operates, the $\text{Zn}(s)$ electrode increases in mass and the $\text{Al}(s)$ electrode decreases in mass. A data table with the standard reduction potentials for the substances follows the diagram.



Half-Reaction	E° (V)
$\text{Zn}^{2+}(aq) + 2e^- \rightarrow \text{Zn}(s)$	-0.76
$\text{Al}^{3+}(aq) + 3e^- \rightarrow \text{Al}(s)$	-1.66

- A. Write the half-reaction for the oxidation that occurs at the anode.
- B. Write the balanced net ionic equation for the overall reaction that occurs in the galvanic cell.
- C. Initially, each electrode has a mass of 50.0 g. The cell is allowed to run for a period of time and is then stopped. Which electrode's mass changed the most? Justify your answer with a calculation.

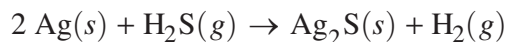
AP CHEMISTRY 2025 FREE-RESPONSE QUESTIONS

Reduction Half-Reaction	E° (V)
$\text{Au}^{3+}(aq) + 3e^- \rightarrow \text{Au}(s)$	+1.50
$\text{Zn}^{2+}(aq) + 2e^- \rightarrow \text{Zn}(s)$	-0.76
$\text{Mn}^{2+}(aq) + 2e^- \rightarrow \text{Mn}(s)$	-1.19
$\text{Al}^{3+}(aq) + 3e^- \rightarrow \text{Al}(s)$	-1.66
$\text{Be}^{2+}(aq) + 2e^- \rightarrow \text{Be}(s)$	-1.85

- D. The standard Zn/Al cell has a value of E°_{cell} equal to 0.90 V. The scientist needs a galvanic cell that produces a greater voltage. The scientist has access to the chemical systems in the table. If the scientist uses the Zn half-cell and one of the other options from the table, what is the MAXIMUM voltage that could be generated at standard conditions?

Begin your response to **QUESTION 3** on this page.

3. Sterling silver is an alloy that is commonly used to make jewelry and consists of 92.5% silver and 7.5% other metals, such as copper, by mass. Over time, the alloy can form a tarnish of $\text{Ag}_2\text{S}(s)$ when it reacts with hydrogen sulfide, as represented by the following equation.



- (a) What are the oxidation numbers of silver in $\text{Ag}(s)$ and $\text{Ag}_2\text{S}(s)$?

$\text{Ag}(s)$ _____ $\text{Ag}_2\text{S}(s)$ _____

- (b) The following table contains the atomic radii for silver and copper.

Element	Silver (Ag)	Copper (Cu)
Atomic radius (pm)	165	145

- (i) Explain why sterling silver is better classified as a substitutional alloy than as an interstitial alloy.
- (ii) Using principles of atomic structure and Coulomb's law, explain why silver has a larger atomic radius than copper does.

GO ON TO THE NEXT PAGE.

Continue your response to **QUESTION 3** on this page.

The Ag_2S tarnish on sterling silver can be removed until only sterling silver remains. A student weighs a tarnished sterling silver sample both before and after removing the $\text{Ag}_2\text{S}(s)$ (molar mass 247.80 g / mol) and records the data in the following table.

	Before Tarnish Removal	After Tarnish Removal
Mass	409.21 g	398.94 g

(c) Assuming that only $\text{Ag}_2\text{S}(s)$ is removed, calculate the number of moles of silver atoms removed.

Rhodium plating is a process used to protect sterling silver from tarnishing. This involves electroplating (depositing) solid rhodium, $\text{Rh}(s)$, onto the surface of the metal from an acidified solution of $\text{Rh}_2(\text{SO}_4)_3(aq)$. Oxygen gas is produced during this process.

(d) A table of half-reactions related to the overall reaction is provided.

Half-Reaction	E° (V)
$\text{Rh}^{3+}(aq) + 3 e^- \rightarrow \text{Rh}(s)$	+0.80
$\text{O}_2(g) + 4 \text{H}^+(aq) + 4 e^- \rightarrow 2 \text{H}_2\text{O}(l)$	+1.23

(i) Write the balanced net ionic equation for plating $\text{Rh}(s)$ from the acidified $\text{Rh}_2(\text{SO}_4)_3(aq)$ solution.

(ii) Calculate the value of E°_{cell} for the reaction in part (d)(i).

GO ON TO THE NEXT PAGE.

Continue your response to **QUESTION 3** on this page.

(iii) Based on your answer to part (d)(ii), explain why this process requires the use of an external power source.

(e) Calculate the length of time, in seconds, required to plate 2.8 g of Rh(s) onto a piece of sterling silver if 2.0 C / s of current is applied.

GO ON TO THE NEXT PAGE.

CHEMISTRY**SECTION II****Time—1 hour and 45 minutes****7 Questions**

Directions: Questions 1–3 are long free-response questions that require about 23 minutes each to answer and are worth 10 points each. Questions 4–7 are short free-response questions that require about 9 minutes each to answer and are worth 4 points each.

For each question, show your work for each part in the space provided after that part. Examples and equations may be included in your responses where appropriate. For calculations, clearly show the method used and the steps involved in arriving at your answers. You must show your work to receive credit for your answer. Pay attention to significant figures.

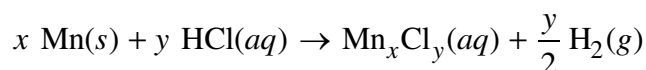
1. Answer the following questions related to manganese compounds.

(a) Manganese has several common oxidation states.

(i) Write the complete electron configuration for an Mn atom in the ground state.

(ii) When manganese forms cations, electrons are lost from which subshell first? Identify both the number and letter associated with the subshell.

A student performs an experiment to produce a manganese salt of unknown composition, $\text{Mn}_x\text{Cl}_y(\text{aq})$, and determine its empirical formula. The student places a sample of $\text{Mn}(\text{s})$ in a beaker containing excess $\text{HCl}(\text{aq})$, as represented by the following equation.

**GO ON TO THE NEXT PAGE.**

Continue your response to **QUESTION 1** on this page.

The student heats the resulting mixture until only $\text{Mn}_x\text{Cl}_y(s)$ remains in the beaker. The data are given in the following table.

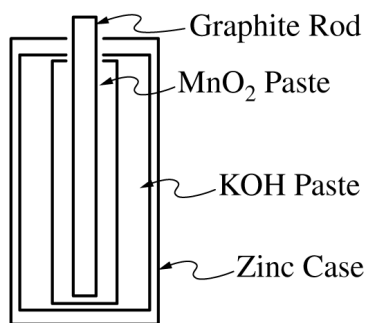
Mass of empty beaker	60.169 g
Mass of beaker and $\text{Mn}(s)$	61.262 g
Mass of beaker and Mn_xCl_y after heating to constant mass	62.673 g

- (b) Calculate the mass of Cl in the sample of $\text{Mn}_x\text{Cl}_y(s)$ remaining in the beaker.
- (c) Calculate the number of moles of Cl in the sample of $\text{Mn}_x\text{Cl}_y(s)$ remaining in the beaker.
- (d) The student determines that 0.0199 mol of Mn was used in the experiment. Use the data to determine the empirical formula of the $\text{Mn}_x\text{Cl}_y(s)$.
- (e) The student repeats the experiment using the same amounts of Mn and HCl and notices that some of the Mn_xCl_y splatters out of the beaker as it is heated to dryness. Will the number of moles of Cl calculated for this trial be greater than, less than, or equal to the number calculated in part (c) ? Justify your answer.

GO ON TO THE NEXT PAGE.

Continue your response to QUESTION 1 on this page.

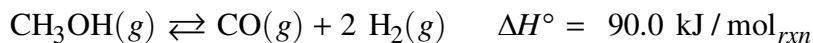
- (f) Another compound of manganese, MnO_2 , is used in alkaline batteries, represented by the following diagram. Some half-reactions are given in the table.



Reduction Half-Reaction	E° (V)
$\text{Zn}^{2+}(aq) + 2 e^- \rightarrow \text{Zn}(s)$	-0.76
$\text{ZnO}(s) + \text{H}_2\text{O}(l) + 2 e^- \rightarrow \text{Zn}(s) + 2 \text{OH}^-(aq)$	-1.28
$2 \text{MnO}_2(s) + \text{H}_2\text{O}(l) + 2 e^- \rightarrow \text{Mn}_2\text{O}_3(s) + 2 \text{OH}^-(aq)$	0.15

- (i) Based on the half-reactions given in the table, write the balanced net ionic equation for the reaction that has the greatest thermodynamic favorability.
- (ii) Calculate the value of E°_{cell} for the overall reaction.
- (iii) Calculate the value of ΔG° in $\text{kJ/mol}_{\text{rxn}}$.
- (iv) A student claims that the total mass of an alkaline battery decreases as the battery operates because the anode loses mass. Do you agree with the student's claim? Justify your answer.

GO ON TO THE NEXT PAGE.



Methanol vapor decomposes to form carbon monoxide gas and hydrogen gas at high temperatures in the presence of a platinum catalyst, as represented by the balanced chemical equation given.

(a) Are the hydrogen atoms oxidized or are they reduced in the forward reaction? Justify your answer in terms of oxidation numbers.

(b) In the following box, draw the complete Lewis electron-dot diagram for the carbon monoxide molecule in which every atom obeys the octet rule. Show all bonding and nonbonding valence electrons.



(c) The values of the standard molar entropies of the compounds involved in the reaction are given in the following table.

Substance	S° (J/(K·mol))
$\text{CH}_3\text{OH}(g)$	240.
$\text{CO}(g)$	198
$\text{H}_2(g)$	131

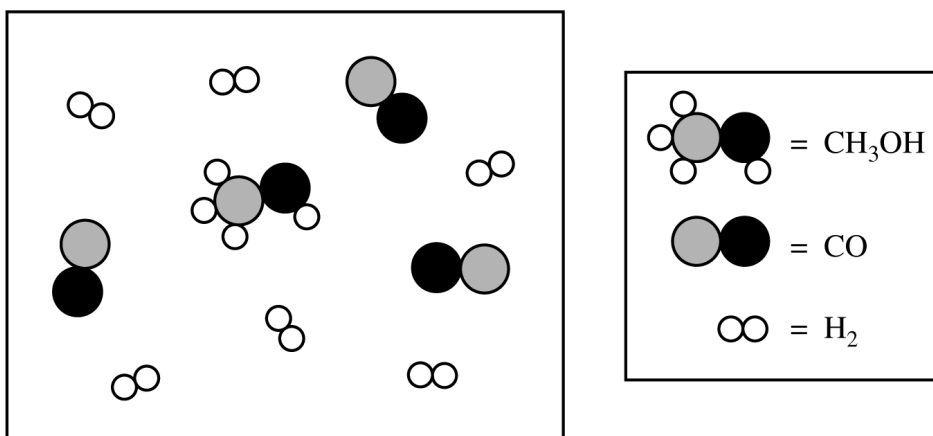
(i) Use the data in the table to calculate the value of the standard entropy change, ΔS° , in J/(K·mol_{rxn}), for the reaction.

GO ON TO THE NEXT PAGE.

Continue your response to **QUESTION 2** on this page.

- (ii) Calculate the value of ΔG° , in $\text{kJ/mol}_{\text{rxn}}$, for the reaction at 375 K. Assume that ΔH° and ΔS° are independent of temperature.

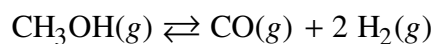
The following particle-level diagram shows a representative sample of the equilibrium mixture represented by the equation given.



- (d) Use information from the particle diagram to calculate the partial pressure of CO at equilibrium when the total pressure of the equilibrium mixture is 12.0 atm.
- (e) Write the expression for the equilibrium constant, K_p , for the reaction.

GO ON TO THE NEXT PAGE.

Continue your response to QUESTION 2 on this page.



The reaction system represented by the equation is allowed to achieve equilibrium at a different temperature. The following table gives the partial pressure of each species in the equilibrium mixture.

Substance	Partial Pressure at Different Temperature
$\text{CH}_3\text{OH}(g)$	2.7 atm
$\text{CO}(g)$	4.2 atm
$\text{H}_2(g)$	8.4 atm

(f) Use the information in the table to calculate the value of the equilibrium constant, K_p , at the new temperature.

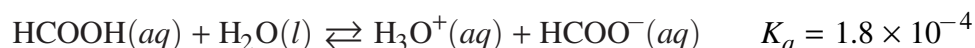
(g) The volume of the container is rapidly doubled with no change in temperature. As equilibrium is re-established, does the number of moles of $\text{CH}_3\text{OH}(g)$ increase, decrease, or remain the same? Justify your answer by comparing the value of the reaction quotient, Q , with the value of the equilibrium constant, K_p .

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CHEMISTRY**SECTION II****Time—1 hour and 45 minutes****7 Questions****YOU MAY USE YOUR CALCULATOR FOR THIS SECTION.**

Directions: Questions 1–3 are long free-response questions that require about 23 minutes each to answer and are worth 10 points each. Questions 4–7 are short free-response questions that require about 9 minutes each to answer and are worth 4 points each.

For each question, show your work for each part in the space provided after that part. Examples and equations may be included in your responses where appropriate. For calculations, clearly show the method used and the steps involved in arriving at your answers. You must show your work to receive credit for your answer. Pay attention to significant figures.



1. Methanoic acid, HCOOH , ionizes according to the equation above.

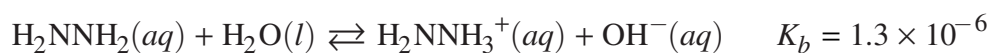
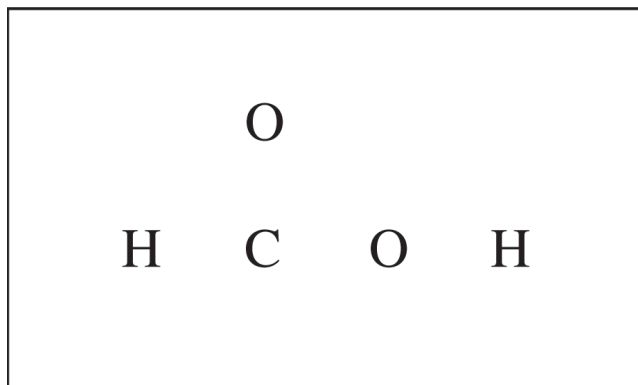
(a) Write the expression for the equilibrium constant, K_a , for the reaction.

(b) Calculate the pH of a 0.25 M solution of HCOOH .

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Use a pencil or pen with black or dark blue ink only. Do NOT write your name. Do NOT write outside the box.

(c) In the box below, complete the Lewis electron-dot diagram for HCOOH . Show all bonding and nonbonding valence electrons.



(d) In aqueous solution, the compound H_2NNH_2 reacts according to the equation above. A 50.0 mL sample of 0.25 M $\text{H}_2\text{NNH}_2(aq)$ is combined with a 50.0 mL sample of 0.25 M $\text{HCOOH}(aq)$.

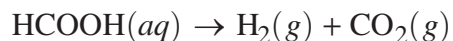
(i) Write the balanced net ionic equation for the reaction that occurs when H_2NNH_2 is combined with HCOOH .

(ii) Is the resulting solution acidic, basic, or neutral? Justify your answer.

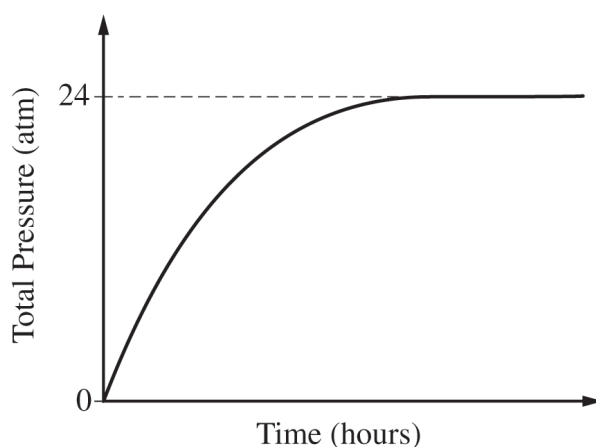
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Use a pencil or pen with black or dark blue ink only. Do NOT write your name. Do NOT write outside the box.

When a catalyst is added to a solution of $\text{HCOOH}(aq)$, the reaction represented by the following equation occurs.



(e) Is the reaction a redox reaction? Justify your answer.



(f) The reaction occurs in a rigid 4.3 L vessel at 25°C , and the total pressure is monitored, as shown in the graph above. The vessel originally did not contain any gas. Calculate the number of moles of $\text{CO}_2(g)$ produced in the reaction. (Assume that the amount of $\text{CO}_2(g)$ dissolved in the solution is negligible.)

(g) After the reaction has proceeded for several minutes, does the amount of catalyst increase, decrease, or remain the same? Justify your answer.

GO ON TO THE NEXT PAGE.

Use a pencil or pen with black or dark blue ink only. Do NOT write your name. Do NOT write outside the box.

2. Answer the following questions relating to the chemistry of the halogens.

- (a) The molecular formulas of diatomic bromine, chlorine, fluorine, and iodine are written below. Circle the formula of the molecule that has the longest bond length. Justify your choice in terms of atomic structure.



A chemistry teacher wants to prepare Br_2 . The teacher has access to the following three reagents: $\text{NaBr}(aq)$, $\text{Cl}_2(g)$, and $\text{I}_2(s)$.

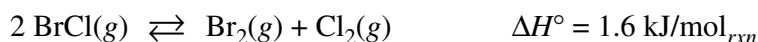
Half-Reaction	E° at 25°C (V)
$\text{Br}_2 + 2 e^- \rightarrow 2 \text{Br}^-$	1.07
$\text{Cl}_2 + 2 e^- \rightarrow 2 \text{Cl}^-$	1.36
$\text{I}_2 + 2 e^- \rightarrow 2 \text{I}^-$	0.53

- (b) Using the data in the table above, write the balanced equation for the thermodynamically favorable reaction that will produce Br_2 when the teacher combines two of the reagents. Justify that the reaction is thermodynamically favorable by calculating the value of E° for the reaction.

Br_2 and Cl_2 can react to form the compound BrCl .

- (c) The boiling point of Br_2 is 332 K, whereas the boiling point of BrCl is 278 K. Explain this difference in boiling point in terms of all the intermolecular forces present between molecules of each substance.

The compound BrCl can decompose into Br_2 and Cl_2 , as represented by the balanced chemical equation below.



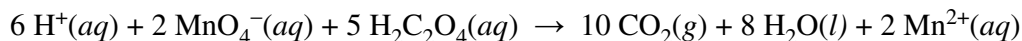
A 0.100 mole sample of pure $\text{BrCl}(g)$ is placed in a previously evacuated, rigid 2.00 L container at 298 K. Eventually the system reaches equilibrium according to the equation above.

- (d) Calculate the pressure in the container before equilibrium is established.
- (e) Write the expression for the equilibrium constant, K_{eq} , for the decomposition of BrCl .

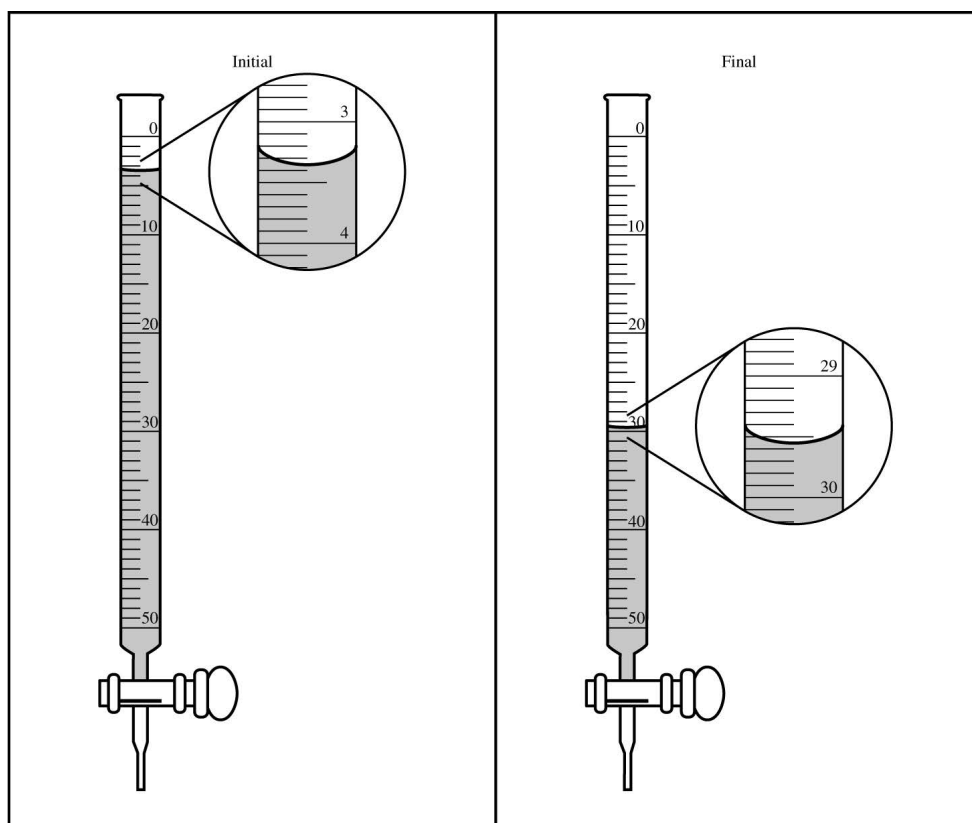
After the system has reached equilibrium, 42 percent of the original BrCl sample has decomposed.

- (f) Determine the value of K_{eq} for the decomposition reaction of BrCl at 298 K.
- (g) Calculate the bond energy of the Br-Cl bond, in kJ/mol, using ΔH° for the reaction (1.6 kJ/mol_{rxn}) and the information in the following table.

Bond	Bond Energy (kJ/mol)
Br – Br	193
Cl – Cl	243
Br – Cl	?



7. A student dissolved a 0.139 g sample of oxalic acid, $\text{H}_2\text{C}_2\text{O}_4$, in water in an Erlenmeyer flask. Then the student titrated the $\text{H}_2\text{C}_2\text{O}_4$ solution in the flask with a solution of KMnO_4 , which has a dark purple color. The balanced chemical equation for the reaction that occurred during the titration is shown above.
- (a) Identify the species that was reduced in the titration reaction. Justify your answer in terms of oxidation numbers.
- (b) The student used a 50.0 mL buret to add the $\text{KMnO}_4(aq)$ to the $\text{H}_2\text{C}_2\text{O}_4(aq)$ until a faint lavender color was observed in the flask, an indication that the end point of the titration had been reached. The initial and final volume readings of the solution in the buret are shown below. Write down the initial reading and the final reading and use them to determine the volume of $\text{KMnO}_4(aq)$ that was added during the titration.



- (c) Given that the concentration of $\text{KMnO}_4(aq)$ was 0.0235 M, calculate the number of moles of MnO_4^- ions that completely reacted with the $\text{H}_2\text{C}_2\text{O}_4$.
- (d) The student proposes to perform another titration using a 0.139 g sample of $\text{H}_2\text{C}_2\text{O}_4$, but this time using 0.00143 M $\text{KMnO}_4(aq)$ in the buret. Would this titrant concentration be a reasonable choice to use if the student followed the same procedure and used the same equipment as before? Justify your response.

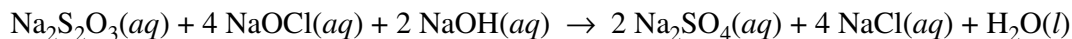
STOP

END OF EXAM

CHEMISTRY**Section II****Time—1 hour and 45 minutes****7 Questions****YOU MAY USE YOUR CALCULATOR FOR THIS SECTION.**

Directions: Questions 1–3 are long free-response questions that require about 23 minutes each to answer and are worth 10 points each. Questions 4–7 are short free-response questions that require about 9 minutes each to answer and are worth 4 points each.

Write your response in the space provided following each question. Examples and equations may be included in your responses where appropriate. For calculations, clearly show the method used and the steps involved in arriving at your answers. You must show your work to receive credit for your answer. Pay attention to significant figures.



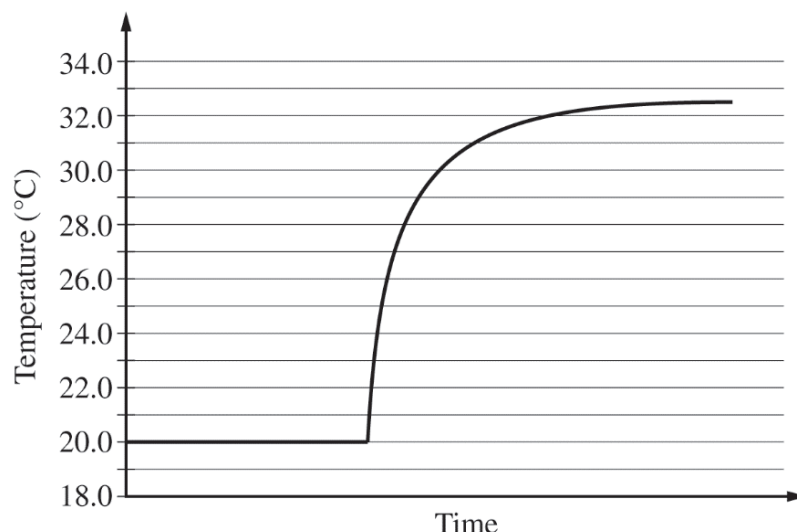
1. A student performs an experiment to determine the value of the enthalpy change, ΔH_{rxn}° , for the oxidation-reduction reaction represented by the balanced equation above.
- (a) Determine the oxidation number of Cl in NaOCl.
- (b) Calculate the number of grams of $\text{Na}_2\text{S}_2\text{O}_3$ needed to prepare 100.00 mL of 0.500 M $\text{Na}_2\text{S}_2\text{O}_3(aq)$.

In the experiment, the student uses the solutions shown in the table below.

Solution	Concentration (M)	Volume (mL)
$\text{Na}_2\text{S}_2\text{O}_3(aq)$	0.500	5.00
$\text{NaOCl}(aq)$	0.500	5.00
$\text{NaOH}(aq)$	0.500	5.00

- (c) Using the balanced equation for the oxidation-reduction reaction and the information in the table above, determine which reactant is the limiting reactant. Justify your answer.

The solutions, all originally at 20.0°C, are combined in an insulated calorimeter. The temperature of the reaction mixture is monitored, as shown in the graph below.



- (d) According to the graph, what is the temperature change of the reaction mixture?
- (e) The mass of the reaction mixture inside the calorimeter is 15.21 g.
- Calculate the magnitude of the heat energy, in joules, that is released during the reaction. Assume that the specific heat of the reaction mixture is 3.94 J/(g·°C) and that the heat absorbed by the calorimeter is negligible.
 - Using the balanced equation for the oxidation-reduction reaction and your answer to part (c), calculate the value of the enthalpy change of the reaction, ΔH_{rxn}° , in kJ/mol_{rxn}. Include the appropriate algebraic sign with your answer.

The student repeats the experiment, but this time doubling the volume of each of the reactants, as shown in the table below.

Solution	Concentration (M)	Volume (mL)
Na ₂ S ₂ O ₃ (aq)	0.500	10.0
NaOCl(aq)	0.500	10.0
NaOH(aq)	0.500	10.0

- (f) The magnitude of the enthalpy change, ΔH_{rxn}° , in kJ/mol_{rxn}, calculated from the results of the second experiment is the same as the result calculated in part (e)(ii). Explain this result.
- (g) Write the balanced net ionic equation for the given reaction.

3. Answer the following questions relating to Fe and its ions, Fe^{2+} and Fe^{3+} .

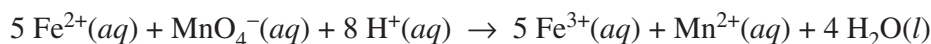
(a) Write the ground-state electron configuration of the Fe^{2+} ion.

Ion	Ionic Radius (pm)
Fe^{2+}	92
Fe^{3+}	79

(b) The radii of the ions are given in the table above. Using principles of atomic structure, explain why the radius of the Fe^{2+} ion is larger than the radius of the Fe^{3+} ion.

(c) Fe^{3+} ions interact more strongly with water molecules in aqueous solution than Fe^{2+} ions do. Give one reason for this stronger interaction, and justify your answer using Coulomb's law.

A student obtains a solution that contains an unknown concentration of $\text{Fe}^{2+}(\text{aq})$. To determine the concentration of $\text{Fe}^{2+}(\text{aq})$ in the solution, the student titrates a sample of the solution with $\text{MnO}_4^-(\text{aq})$, which converts $\text{Fe}^{2+}(\text{aq})$ to $\text{Fe}^{3+}(\text{aq})$, as represented by the following equation.



(d) Write the balanced equation for the half-reaction for the oxidation of $\text{Fe}^{2+}(\text{aq})$ to $\text{Fe}^{3+}(\text{aq})$.

(e) The student titrates a 10.0 mL sample of the $\text{Fe}^{2+}(\text{aq})$ solution. Calculate the value of $[\text{Fe}^{2+}]$ in the solution if it takes 17.48 mL of added 0.0350 M $\text{KMnO}_4(\text{aq})$ to reach the equivalence point of the titration.

To deliver the 10.0 mL sample of the $\text{Fe}^{2+}(\text{aq})$ solution in part (e), the student has the choice of using one of the pieces of glassware listed below.

- 25 mL buret
- 25 mL graduated cylinder
- 25 mL beaker
- 25 mL volumetric flask

(f) Explain why the 25 mL volumetric flask would be a poor choice to use for delivering the required volume of the $\text{Fe}^{2+}(\text{aq})$ solution.

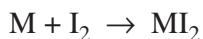
In a separate experiment, the student is given a sample of powdered $\text{Fe}(\text{s})$ that contains an inert impurity. The student uses a procedure to oxidize the $\text{Fe}(\text{s})$ in the sample to $\text{Fe}_2\text{O}_3(\text{s})$. The student collects the following data during the experiment.

Mass of $\text{Fe}(\text{s})$ with inert impurity	6.724 g
Mass of $\text{Fe}_2\text{O}_3(\text{s})$ produced	7.531 g

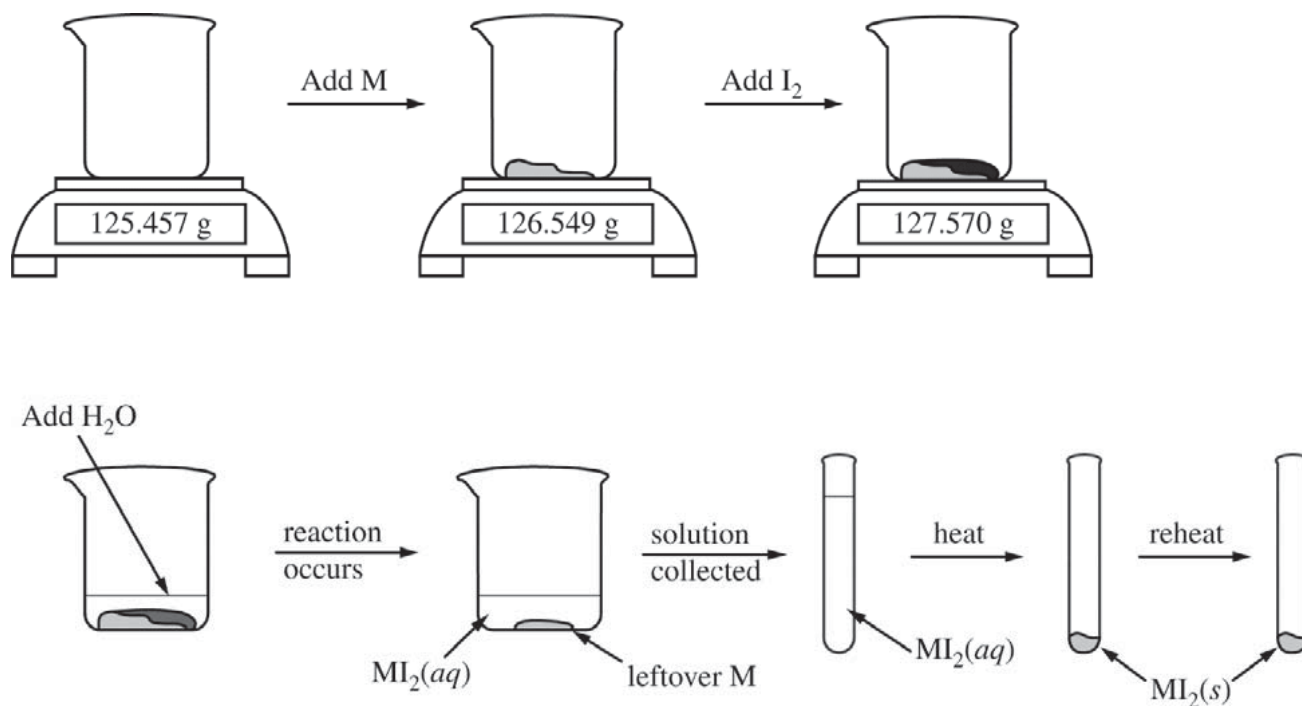
(g) Calculate the number of moles of Fe in the $\text{Fe}_2\text{O}_3(\text{s})$ produced.

(h) Calculate the percent by mass of Fe in the original sample of powdered $\text{Fe}(\text{s})$ with the inert impurity.

(i) If the oxidation of the $\text{Fe}(\text{s})$ in the original sample was incomplete so that some of the 7.531 g of product was $\text{FeO}(\text{s})$ instead of $\text{Fe}_2\text{O}_3(\text{s})$, would the calculated mass percent of $\text{Fe}(\text{s})$ in the original sample be higher, lower, or the same as the actual mass percent of $\text{Fe}(\text{s})$? Justify your answer.



3. To determine the molar mass of an unknown metal, M, a student reacts iodine with an excess of the metal to form the water-soluble compound MI_2 , as represented by the equation above. The reaction proceeds until all of the I_2 is consumed. The $\text{MI}_2(aq)$ solution is quantitatively collected and heated to remove the water, and the product is dried and weighed to constant mass. The experimental steps are represented below, followed by a data table.



Data for Unknown Metal Lab	
Mass of beaker	125.457 g
Mass of beaker + metal M	126.549 g
Mass of beaker + metal M + I ₂	127.570 g
Mass of MI_2 , first weighing	1.284 g
Mass of MI_2 , second weighing	1.284 g

- (a) Given that the metal M is in excess, calculate the number of moles of I_2 that reacted.
- (b) Calculate the molar mass of the unknown metal M.

The student hypothesizes that the compound formed in the synthesis reaction is ionic.

- (c) Propose an experimental test the student could perform that could be used to support the hypothesis. Explain how the results of the test would support the hypothesis if the substance was ionic.

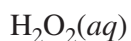
The student hypothesizes that Br_2 will react with metal M more vigorously than I_2 did because Br_2 is a liquid at room temperature.

- (d) Explain why I_2 is a solid at room temperature whereas Br_2 is a liquid. Your explanation should clearly reference the types and relative strengths of the intermolecular forces present in each substance.

While cleaning up after the experiment, the student wishes to dispose of the unused solid I_2 in a responsible manner. The student decides to convert the solid I_2 to $\text{I}^-(aq)$ anion. The student has access to three solutions, $\text{H}_2\text{O}_2(aq)$, $\text{Na}_2\text{S}_2\text{O}_3(aq)$, and $\text{Na}_2\text{S}_4\text{O}_6(aq)$, and the standard reduction table shown below.

Half reaction	E° (V)
$\text{S}_4\text{O}_6^{2-}(aq) + 2 e^- \rightarrow 2 \text{S}_2\text{O}_3^{2-}(aq)$	0.08
$\text{I}_2(s) + 2 e^- \rightarrow 2 \text{I}^-(aq)$	0.54
$\text{O}_2(g) + 2 \text{H}^+(aq) + 2 e^- \rightarrow \text{H}_2\text{O}_2(aq)$	0.68

- (e) Which solution should the student add to $\text{I}_2(s)$ to reduce it to $\text{I}^-(aq)$? Circle your answer below. Justify your answer, including a calculation of E° for the overall reaction.



- (f) Write the balanced net-ionic equation for the reaction between I_2 and the solution you selected in part (e).