Question 5

$$5\ Fe^{2+}(aq)\ +\ MnO_4^-(aq)\ +\ 8\ H^+(aq)\ \rightarrow\ 5\ Fe^{3+}(aq)\ +\ Mn^{2+}(aq)\ +\ 4\ H_2O(l)$$

The mass percent of iron in a soluble iron(II) compound is measured using a titration based on the balanced equation above.

(a) What is the oxidation number of manganese in the permanganate ion, $MnO_4^-(aq)$?

+7	One point is earned for the correct oxidation number.

(b) Identify the reducing agent in the reaction represented above.

$Fe^{2+}(aq)$	One point is earned for the correct iron ion.

The mass of a sample of the iron(II) compound is carefully measured before the sample is dissolved in distilled water. The resulting solution is acidified with $H_2SO_4(aq)$. The solution is then titrated with $MnO_4^-(aq)$ until the end point is reached.

(c) Describe the color change that occurs in the flask when the end point of the titration has been reached. Explain why the color of the solution changes at the end point.

The solution in the flask changes from colorless to faint purple-pink at the endpoint of the titration.	One point is earned for stating that a faint pink color appears (unless indication of acid-base reaction).
At the endpoint there is no $Fe^{2+}(aq)$ left in the flask to reduce the colored permanganate ion, so when a small amount of permanganate ion is added after the endpoint, the unreacted permanganate ion present in the solution colors the solution faint purple/pink.	One point is earned for a correct explanation involving excess MnO_4^- after all Fe^{2+} has reacted.

(d) Let the variables g, M, and V be defined as follows:

g = the mass, in grams, of the sample of the iron(II) compound

M = the molarity of the $MnO_4^-(aq)$ used as the titrant

V = the volume, in liters, of $MnO_4^-(aq)$ added to reach the end point

In terms of these variables, the number of moles of $MnO_4^-(aq)$ added to reach the end point of the titration is expressed as $M \times V$. Using the variables defined above, the molar mass of iron (55.85 g mol^{-1}), and the coefficients in the balanced chemical equation, write the expression for each of the following quantities.

Question 5 (continued)

(i) The number of moles of iron in the sample

$\text{mol Fe}^{2+} = 5 \times M \times V$ **OR** $\text{mol Fe}^{2+} = \dfrac{5 \text{ mol Fe}^{2+}}{1 \text{ mol MnO}_4^{-}} \times M \times V$	One point is earned for either expression.

(ii) The mass of iron in the sample, in grams

$\text{mass Fe} = 5 \times M \times V \times 55.85 \text{ g mol}^{-1}$ **OR** $\text{mass Fe} = \text{mol Fe}^{2+} \times 55.85 \text{ g mol}^{-1}$	One point is earned for the answer in part (d)(i) multiplied by 55.85.

(iii) The mass percent of iron in the compound

$\text{mass \% Fe} = \dfrac{5 \times M \times V \times 55.85}{g} \times 100$ **OR** $\text{mass \% Fe} = \dfrac{\text{mass Fe}}{g} \times 100$	One point is earned for the answer in part (d)(ii) divided by g. One point is earned for converting to percent.

(e) What effect will adding too much titrant have on the experimentally determined value of the mass percent of iron in the compound? Justify your answer.

The experimentally determined mass percent of iron in the compound will be too large. V is too large $\Rightarrow$ expression in (d)(iii) above is too large	One point is earned for stating that the mass percent is too large, with justification.

5A, 1

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 graded 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.

$$5\,Fe^{2+}(aq) + \overset{7+}{MnO_4^-}(aq) + 8\,H^+(aq) \rightarrow 5\,Fe^{3+}(aq) + \overset{2+}{Mn^{2+}}(aq) + 4\,H_2O(l)$$

reduced

5. The mass percent of iron in a soluble iron(II) compound is measured using a titration based on the balanced equation above.

(a) What is the oxidation number of manganese in the permanganate ion, $MnO_4^-(aq)$?

(b) Identify the reducing agent in the reaction represented above.

Fe^{2+}

The mass of a sample of the iron(II) compound is carefully measured before the sample is dissolved in distilled water. The resulting solution is acidified with $H_2SO_4(aq)$. The solution is then titrated with $MnO_4^-(aq)$ until the end point is reached.

(c) Describe the color change that occurs in the flask when the end point of the titration has been reached. Explain why the color of the solution changes at the end point.

(d) Let the variables g, M, and V be defined as follows:

g = the mass, in grams, of the sample of the iron(II) compound

M = the molarity of the $MnO_4^-(aq)$ used as the titrant

V = the volume, in liters, of $MnO_4^-(aq)$ added to reach the end point

In terms of these variables, the number of moles of $MnO_4^-(aq)$ added to reach the end point of the titration is expressed as $M \times V$. Using the variables defined above, the molar mass of iron (55.85 g mol^{-1}), and the coefficients in the balanced chemical equation, write the expression for each of the following quantities.

(i) The number of moles of iron in the sample

(ii) The mass of iron in the sample, in grams

(iii) The mass percent of iron in the compound

(e) What effect will adding too much titrant have on the experimentally determined value of the mass percent of iron in the compound? Justify your answer.

(a) $\overset{7+}{MnO_4^-}$ $\boxed{7+}$

(b) $\boxed{Fe^{2+}}$

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5A2

ADDITIONAL PAGE FOR ANSWERING QUESTION 5.

(c) When MnO_4^- or purplish pink color persists, that means end point has been reached.
It changes because all the Fe^{2+} ions (limiting reagent) have reacted with MnO_4^- so there is excess.
So turns from clearish yellow to a faint pink

(d) (i) $\frac{5\ Fe^{2+}}{1\ MnO_4^-} = \frac{\#\text{ moles of } Fe^{2+}}{M \times V}$

$\#\text{ moles of } Fe^{2+} = \boxed{5 \times M \times V}$

(ii) $\#\text{ moles } Fe^{2+}\left(\frac{55.85\ g}{mol}\right)$

$= \boxed{5 \times M \times V \times 55.85[g/mol]}$

(iii) $\frac{g\ Fe^{2+}}{g\ sample} \times 100\%$

$\boxed{\frac{5 \times M \times V \times 55.85[g/mol]}{g} \times 100\%}$

(e) $\frac{5 \times M \times V\uparrow \times 55.85[g/mol]}{g} \times 100\% = \%\text{ mass}$

titrant is MnO_4^- so too much $\uparrow V$

since $V \propto \%\text{ mass}$

$\uparrow V = \uparrow \%\text{ mass}$

$\boxed{\text{mass \% of iron} \uparrow}$

GO ON TO THE NEXT PAGE.

5B1

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 graded 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.

$$5\,Fe^{2+}(aq) + MnO_4^-(aq) + 8\,H^+(aq) \rightarrow 5\,Fe^{3+}(aq) + Mn^{2+}(aq) + 4\,H_2O(l)$$

5. The mass percent of iron in a soluble iron(II) compound is measured using a titration based on the balanced equation above.

(a) What is the oxidation number of manganese in the permanganate ion, $MnO_4^-(aq)$?

(b) Identify the reducing agent in the reaction represented above.

The mass of a sample of the iron(II) compound is carefully measured before the sample is dissolved in distilled water. The resulting solution is acidified with $H_2SO_4(aq)$. The solution is then titrated with $MnO_4^-(aq)$ until the end point is reached.

(c) Describe the color change that occurs in the flask when the end point of the titration has been reached. Explain why the color of the solution changes at the end point.

(d) Let the variables g, M, and V be defined as follows:

g = the mass, in grams, of the sample of the iron(II) compound

M = the molarity of the $MnO_4^-(aq)$ used as the titrant

V = the volume, in liters, of $MnO_4^-(aq)$ added to reach the end point

In terms of these variables, the number of moles of $MnO_4^-(aq)$ added to reach the end point of the titration is expressed as $M \times V$. Using the variables defined above, the molar mass of iron (55.85 g mol^{-1}), and the coefficients in the balanced chemical equation, write the expression for each of the following quantities.

(i) The number of moles of iron in the sample

(ii) The mass of iron in the sample, in grams

(iii) The mass percent of iron in the compound

(e) What effect will adding too much titrant have on the experimentally determined value of the mass percent of iron in the compound? Justify your answer.

a) Since the oxidation number of the O atoms is -2 and the overall oxidation number must equal the charge on the ion (-1), the oxidation number of Mn is +7.

b) Since Fe^{2+} loses electrons to manganese and becomes Fe^{3+}, Fe^{2+} is the reducing agent.

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ADDITIONAL PAGE FOR ANSWERING QUESTION 5.

c) At the end point, the color changes from purple to blue. This is because MnO_4^- ions are purple in solution, but they are consumed in titration as Fe^{3+} and Mn^{2+} ions are produced. Fe^{3+} ions are blue in solution, so their production causes the color change.

d) (i) moles iron = $M \times V \times \frac{5 \text{ mol } Fe^{2+}}{1 \text{ mol } MnO_4^-}$

(ii) mass of iron = $M \times V \times \frac{5 \text{ mol } Fe^{2+}}{1 \text{ mol } MnO_4^-} \times 55.85 \text{ g mol}^{-1}$

(iii) mass % iron = $\dfrac{\left(M \times V \times \frac{5 \text{ mol } Fe^{2+}}{1 \text{ mol } MnO_4^-} \times 55.85 \text{ g mol}^{-1}\right)}{g} \times 100$

e) Adding too much titrant will make the measured value of V too high. Since V is in the numerator of the equation for mass %, the calculated value of mass % of iron will be higher than the actual value.

 5C,

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 graded 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.

$$\overset{+2}{5\,Fe^{2+}}(aq) + \overset{+7\;-2}{MnO_4^-}(aq) + 8\,\overset{+1}{H^+}(aq) \rightarrow 5\,\overset{+3}{Fe^{3+}}(aq) + \overset{+2}{Mn^{2+}}(aq) + 4\,\overset{+1\;-2}{H_2O}(l)$$

5. The mass percent of iron in a soluble iron(II) compound is measured using a titration based on the balanced equation above.

(a) What is the oxidation number of manganese in the permanganate ion, $MnO_4^-(aq)$?

(b) Identify the reducing agent in the reaction represented above.

gives of e^- - Fe^{2+}

The mass of a sample of the iron(II) compound is carefully measured before the sample is dissolved in distilled water. The resulting solution is acidified with $H_2SO_4(aq)$. The solution is then titrated with $MnO_4^-(aq)$ until the end point is reached.

(c) Describe the color change that occurs in the flask when the end point of the titration has been reached. Explain why the color of the solution changes at the end point.

(d) Let the variables g, M, and V be defined as follows:

g = the mass, in grams, of the sample of the iron(II) compound

M = the molarity of the $MnO_4^-(aq)$ used as the titrant

V = the volume, in liters, of $MnO_4^-(aq)$ added to reach the end point

In terms of these variables, the number of moles of $MnO_4^-(aq)$ added to reach the end point of the titration is expressed as $M \times V$. Using the variables defined above, the molar mass of iron (55.85 g mol^{-1}), and the coefficients in the balanced chemical equation, write the expression for each of the following quantities.

(i) The number of moles of iron in the sample

(ii) The mass of iron in the sample, in grams

(iii) The mass percent of iron in the compound

(e) What effect will adding too much titrant have on the experimentally determined value of the mass percent of iron in the compound? Justify your answer.

a) +7 oxidation number

b) Fe^{2+} is the reducing agent.

 5C2

ADDITIONAL PAGE FOR ANSWERING QUESTION 5.

c.) at the end point the color changes from clear to red because of the presence of Iron ions in solution.

d) i) moles of iron in sample.

$\boxed{5M \cdot V}$ = moles of iron in sample.
b/c of the 5:1 molar ratio of MnO_4^- to Fe^{2+}

ii) $\boxed{1g}$ = mass of iron in the sample b/c that's the given value of g.

$\boxed{5M \cdot V \cdot 55.85}$ is also this value because the number of moles multiplied by the molar mass yeilds the total mass of a substance.

iii) $$\frac{5MV \cdot 55.85}{5MV \cdot 55.85 + MV \cdot \frac{g\,MnO_4^-}{1\,mol\,MnO_4^-} + 4MV \cdot \frac{g\,H_2O}{1mol\,H_2O}}$$

e) too much titrant will result in a higher mass percent value for iron in the compound.

Question 5

Overview

The intent of the laboratory question was twofold: to evaluate students' knowledge and laboratory experience in performing a redox titration, and to assess their ability to communicate conceptually using data collected in the laboratory. In parts (a) and (b) students were asked to identify the oxidation number of Mn in MnO_4^- and also to identify the reducing agent in the given reaction. Part (c) required them to identify the color change in the flask at the endpoint of the titration and the reason for the color change. Part (d) asked students to use assigned variables to provide the mathematical expressions necessary to calculate the percentage of iron in an unknown sample. Part (e) was an error analysis component in which students were asked to predict the effect of adding too much titrant and had to justify their answer.

Sample: 5A
Score: 9

This response earned all 9 points: 1 for part (a), 1 for part (b), 2 for part (c), 1 for part (d)(i), 1 for part (d)(ii), 2 for part (d)(iii), and 1 for part (e).

Sample: 5B
Score: 7

This response earned 1 point for part (a) and 1 point for part (b). No points were earned for part (c): the student correctly identifies the purple color for MnO_4^-; however, the response indicates that this is the initial color and incorrectly identifies the ending color as blue (due to Fe^{2+} in solution). All points were earned in parts (d) and (e).

Sample: 5C
Score: 4

This response earned 1 point for part (a) and 1 point for part (b). No points were earned for part (c): the student indicates a final color of red due to the presence of iron ions. Parts (d)(i) and (d)(ii) each earned 1 point. No points were earned for part (d)(iii); the expression in part (d)(ii) is used correctly in the numerator, but the denominator includes many extra components, and there is no attempt to convert into a percentage. No point was earned in part (e); the effect stated is correct, but no explanation is given.