

**AP<sup>®</sup> CHEMISTRY**  
**2018 SCORING GUIDELINES**

**Question 3**

Answer the following questions relating to Fe and its ions, Fe<sup>2+</sup> and Fe<sup>3+</sup>.

- (a) Write the ground-state electron configuration of the Fe<sup>2+</sup> ion.

$1s^2 2s^2 2p^6 3s^2 3p^6 3d^6$ OR $[\text{Ar}] 3d^6$	1 point is earned for a correct electron configuration.
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Ion	Ionic Radius (pm)
Fe <sup>2+</sup>	92
Fe <sup>3+</sup>	79

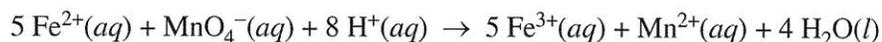
- (b) The radii of the ions are given in the table above. Using principles of atomic structure, explain why the radius of the Fe<sup>2+</sup> ion is larger than the radius of the Fe<sup>3+</sup> ion.

Both ions have the same nuclear charge; however, the greater number of electrons in the outermost shell of Fe <sup>2+</sup> results in greater electron-electron repulsion within that shell, leading to a larger radius.	1 point is earned for a valid explanation.
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- (c) Fe<sup>3+</sup> ions interact more strongly with water molecules in aqueous solution than Fe<sup>2+</sup> ions do. Give one reason for this stronger interaction, and justify your answer using Coulomb's law.

Coulomb's law: $F \propto \frac{q_1 q_2}{r^2}$ (need not be explicitly stated) In comparison to the Fe <sup>2+</sup> ion, the Fe <sup>3+</sup> ion has a higher charge. OR The smaller size of Fe <sup>3+</sup> allows it to get closer to a water molecule.	1 point is earned for a valid explanation.
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A student obtains a solution that contains an unknown concentration of Fe<sup>2+</sup>(aq). To determine the concentration of Fe<sup>2+</sup>(aq) in the solution, the student titrates a sample of the solution with MnO<sub>4</sub><sup>-</sup>(aq), which converts Fe<sup>2+</sup>(aq) to Fe<sup>3+</sup>(aq), as represented by the following equation.



- (d) Write the balanced equation for the half-reaction for the oxidation of Fe<sup>2+</sup>(aq) to Fe<sup>3+</sup>(aq).

$\text{Fe}^{2+}(\text{aq}) \rightarrow \text{Fe}^{3+}(\text{aq}) + e^{-}$	1 point is earned for the correct half-reaction.
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**Question 3 (continued)**

- (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.

$17.48 \text{ mL} \times \frac{0.0350 \text{ mol KMnO}_4}{1000 \text{ mL}} = 0.000612 \text{ mol KMnO}_4$ $0.000612 \text{ mol KMnO}_4 \times \frac{5 \text{ mol Fe}^{2+}}{1 \text{ mol KMnO}_4} = 0.003059 \text{ mol Fe}^{2+}$ $\frac{0.003059 \text{ mol Fe}^{2+}}{0.0100 \text{ L}} = 0.306 \text{ M Fe}^{2+}$	<p>1 point is earned for calculating the number of moles of <math>\text{KMnO}_4</math> (may be implicit).</p> <p>1 point is earned for the correct concentration of <math>\text{Fe}^{2+}(\text{aq})</math>.</p>
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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 beaker
  - 25 mL graduated cylinder
  - 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.

The volumetric flask is designed to contain only 25.00 mL precisely.	1 point is earned for a valid explanation.
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**Question 3 (continued)**

In a separate experiment, the student is given a sample of powdered Fe(s) that contains an inert impurity. The student uses a procedure to oxidize the Fe(s) in the sample to Fe<sub>2</sub>O<sub>3</sub>(s). The student collects the following data during the experiment.

Mass of Fe(s) with inert impurity	6.724 g
Mass of Fe <sub>2</sub> O <sub>3</sub> (s) produced	7.531 g

(g) Calculate the number of moles of Fe in the Fe<sub>2</sub>O<sub>3</sub>(s) produced.

$7.531 \text{ g Fe}_2\text{O}_3 \times \frac{1 \text{ mol Fe}_2\text{O}_3}{159.70 \text{ g Fe}_2\text{O}_3} = 0.04716 \text{ mol Fe}_2\text{O}_3$ $0.04716 \text{ mol Fe}_2\text{O}_3 \times \frac{2 \text{ mol Fe}}{1 \text{ mol Fe}_2\text{O}_3} = 0.09431 \text{ mol Fe}$	1 point is earned for correct calculation.
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(h) Calculate the percent by mass of Fe in the original sample of powdered Fe(s) with the inert impurity.

$0.09431 \text{ mol Fe} \times \frac{55.85 \text{ g Fe}}{1 \text{ mol}} = 5.267 \text{ g Fe}$ $\frac{5.267 \text{ g Fe}}{6.724 \text{ g sample}} \times 100 = 78.33\%$	1 point is earned for correct calculation of the mass percent based on the answer to part (g).
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(i) If the oxidation of the Fe(s) in the original sample was incomplete so that some of the 7.531 g of product was FeO(s) instead of Fe<sub>2</sub>O<sub>3</sub>(s), would the calculated mass percent of Fe(s) in the original sample be higher, lower, or the same as the actual mass percent of Fe(s)? Justify your answer.

<p>The calculated mass percent of Fe would be lower than the actual mass percent of Fe.</p> <p>A sample that contains any FeO (rather than Fe<sub>2</sub>O<sub>3</sub>) will have a higher <u>actual</u> mass percent of Fe than a completely oxidized sample would have. Therefore, when the moles of Fe are calculated (assuming all the mass of the sample is Fe<sub>2</sub>O<sub>3</sub>) the <u>calculated</u> number of moles of Fe, and hence the <u>calculated</u> mass percent of Fe, will be lower.</p>	1 point is earned for the correct answer and a valid explanation.
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