

AP[®] CHEMISTRY
2018 SCORING GUIDELINES

Question 3

Answer the following questions relating to Fe and its ions, Fe²⁺ and Fe³⁺.

(a) Write the ground-state electron configuration of the Fe²⁺ 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 ²⁺	92
Fe ³⁺	79

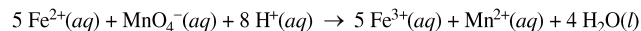
(b) The radii of the ions are given in the table above. Using principles of atomic structure, explain why the radius of the Fe²⁺ ion is larger than the radius of the Fe³⁺ ion.

Both ions have the same nuclear charge; however, the greater number of electrons in the outermost shell of Fe ²⁺ 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) Fe³⁺ ions interact more strongly with water molecules in aqueous solution than Fe²⁺ 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 ²⁺ ion, the Fe ³⁺ ion has a higher charge. OR The smaller size of Fe ³⁺ 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 Fe²⁺(aq). To determine the concentration of Fe²⁺(aq) in the solution, the student titrates a sample of the solution with MnO₄[−](aq), which converts Fe²⁺(aq) to Fe³⁺(aq), as represented by the following equation.



(d) Write the balanced equation for the half-reaction for the oxidation of Fe²⁺(aq) to Fe³⁺(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 Fe²⁺(aq) solution. Calculate the value of [Fe²⁺] in the solution if it takes 17.48 mL of added 0.0350 M KMnO₄(aq) to reach the equivalence point of the titration.

$17.48 \text{ mL} \times \frac{0.0350 \text{ mol KMnO}_4}{1000 \text{ mL}} = 0.000612 \text{ mol KMnO}_4$ $0.000612 \text{ mol KMnO}_4 \times \frac{5 \text{ mol Fe}^{2+}}{1 \text{ mol KMnO}_4} = 0.003059 \text{ mol Fe}^{2+}$ $\frac{0.003059 \text{ mol Fe}^{2+}}{0.0100 \text{ L}} = 0.306 \text{ M Fe}^{2+}$	1 point is earned for calculating the number of moles of KMnO ₄ (may be implicit). 1 point is earned for the correct concentration of Fe ²⁺ (aq).
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To deliver the 10.0 mL sample of the Fe²⁺(aq) solution in part (e), the student has the choice of using one of the pieces of glassware listed below.

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|----------------------------|--------------------------|
| • 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 Fe²⁺(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 Fe₂O₃(s). The student collects the following data during the experiment.

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

(g) Calculate the number of moles of Fe in the Fe₂O₃(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 Fe₂O₃(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.

The calculated mass percent of Fe would be lower than the actual mass percent of Fe. A sample that contains any FeO (rather than Fe₂O₃) 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 Fe₂O₃) the <u>calculated</u> number of moles of Fe, and hence the <u>calculated</u> mass percent of Fe, will be lower.	1 point is earned for the correct answer and a valid explanation.
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