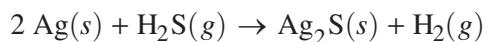


Begin your response to **QUESTION 3** on this page.

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.

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

The  $\text{Ag}_2\text{S}$  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	$E^\circ$ (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  $E_{cell}^\circ$  for the reaction in part (d)(i).

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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.

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**Question 3: Long Answer****10 points**

- (a) For the correct answer: **1 point**



- (b) (i) For a valid explanation: **1 point**

*Silver and copper have similar radii, so the alloy would be substitutional versus interstitial.*

- (ii) For a valid explanation: **1 point**

*Silver has more occupied electron shells ( $n = 5$ ) than copper ( $n = 4$ ); the electrons in the fifth shell experience weaker Coulombic attractions and are farther away from the nucleus.*

**Total for part (b) 2 points**

- (c) For the correct calculated mass of  $\text{Ag}_2\text{S}$  (may be implicit): **1 point**

$$409.21 \text{ g} - 398.94 \text{ g} = 10.27 \text{ g}$$

- For the correct calculated moles of Ag: **1 point**

$$10.27 \text{ g} \times \frac{1 \text{ mol Ag}_2\text{S}}{247.80 \text{ g Ag}_2\text{S}} \times \frac{2 \text{ mol Ag}}{1 \text{ mol Ag}_2\text{S}} = 0.08289 \text{ mol Ag}$$

**Total for part (c) 2 points**

- (d) (i) For the correct balanced equation (state symbols not required): **1 point**



- (ii) For the correct calculated value, consistent with part (d)(i): **1 point**

$$E_{cell}^\circ = +0.80 \text{ V} - 1.23 \text{ V} = -0.43 \text{ V}$$

- (iii) For a correct explanation, consistent with part (d)(ii): **1 point**

*$E_{cell}^\circ$  is negative, which means the reaction is not thermodynamically favorable.*

**Total for part (d) 3 points**

- (e) For the correct calculated value of moles of electrons (may be implicit): **1 point**

$$2.8 \text{ g Rh} \times \frac{1 \text{ mol Rh}}{102.9 \text{ g Rh}} \times \frac{3 \text{ mol } e^-}{1 \text{ mol Rh}} = 0.082 \text{ mol } e^-$$

- For the correct calculated value of time: **1 point**

$$0.082 \text{ mol } e^- \times \frac{96,485 \text{ C}}{1 \text{ mol } e^-} \times \frac{1 \text{ second}}{2.0 \text{ C}} = 3900 \text{ seconds}$$

**Total for part (e) 2 points**

**Total for question 3 10 points**