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 $Ag_2S(s)$ when it reacts with hydrogen sulfide, as represented by the following equation.

$$2\ Ag(s) + H_2S(g) \rightarrow Ag_2S(s) + H_2(g)$$

(a) What are the oxidation numbers of silver in $Ag(s)$ and $Ag_2S(s)$?

$Ag(s)$____________ $Ag_2S(s)$____________

(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 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 $Ag_2S(s)$ (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 $Ag_2S(s)$ 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, $Rh(s)$, onto the surface of the metal from an acidified solution of $Rh_2(SO_4)_3(aq)$. Oxygen gas is produced during this process.

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

Half-Reaction	$E°$ (V)
$Rh^{3+}(aq) + 3\,e^- \rightarrow Rh(s)$	+0.80
$O_2(g) + 4\,H^+(aq) + 4\,e^- \rightarrow 2\,H_2O(l)$	+1.23

(i) Write the balanced net ionic equation for plating $Rh(s)$ from the acidified $Rh_2(SO_4)_3(aq)$ solution.

(ii) Calculate the value of E°_{cell} 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 $\text{Rh}(s)$ 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: Ag(s) __0__ Ag_2S(s) __+1__	**1 point**
(b) (i)	For a valid explanation: *Silver and copper have similar radii, so the alloy would be substitutional versus interstitial.*	**1 point**
(ii)	For a valid explanation: *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.*	**1 point**
	Total for part (b)	**2 points**
(c)	For the correct calculated mass of Ag_2S (may be implicit): $409.21\text{ g} - 398.94\text{ g} = 10.27\text{ g}$	**1 point**
	For the correct calculated moles of Ag: $10.27\text{ g} \times \frac{1\text{ mol }Ag_2S}{247.80\text{ g }Ag_2S} \times \frac{2\text{ mol Ag}}{1\text{ mol }Ag_2S} = 0.08289\text{ mol Ag}$	**1 point**
	Total for part (c)	**2 points**
(d) (i)	For the correct balanced equation (state symbols not required): $4\ Rh^{3+}(aq) + 6\ H_2O(l) \rightarrow 4\ Rh(s) + 3\ O_2(g) + 12\ H^+(aq)$	**1 point**
(ii)	For the correct calculated value, consistent with part (d)(i): $E^\circ_{cell} = +0.80\text{ V} - 1.23\text{ V} = -0.43\text{ V}$	**1 point**
(iii)	For a correct explanation, consistent with part (d)(ii): E°_{cell} *is negative, which means the reaction is not thermodynamically favorable.*	**1 point**
	Total for part (d)	**3 points**
(e)	For the correct calculated value of moles of electrons (may be implicit): $2.8\text{ g Rh} \times \frac{1\text{ mol Rh}}{102.9\text{ g Rh}} \times \frac{3\text{ mol }e^-}{1\text{ mol Rh}} = 0.082\text{ mol }e^-$	**1 point**
	For the correct calculated value of time: $0.082\text{ mol }e^- \times \frac{96{,}485\text{ C}}{1\text{ mol }e^-} \times \frac{1\text{ second}}{2.0\text{ C}} = 3900\text{ seconds}$	**1 point**
	Total for part (e)	**2 points**
	Total for question 3	**10 points**