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

3. Answer the following questions relating to the element aluminum, Al.

(a) Write the complete ground-state electron configuration of an Al atom.

(b) Based on principles of atomic structure, explain why the radius of the Al atom is larger than the radius of the Al^{3+} ion.

A student plans to combine solid aluminum with an aqueous solution of silver ions. The student determines the mass of solid $AgNO_3$ needed to prepare the solution with a specific concentration.

(c) In the following table, briefly list the steps necessary to prepare 200.0 mL of an aqueous solution of $AgNO_3$ using only equipment selected from the choices given. Assume that all appropriate safety measures are already in place. Not all equipment or lines in the table may be needed.

- Solid $AgNO_3$
- Weighing paper and scoop
- 250 mL beakers
- Distilled water
- 200.00 mL volumetric flask
- Pipet
- Balance
- 50.0 mL graduated cylinder

Step	Step Description
1.	Use weighing paper to measure the determined mass of solid $AgNO_3$ on a balance.
2.	

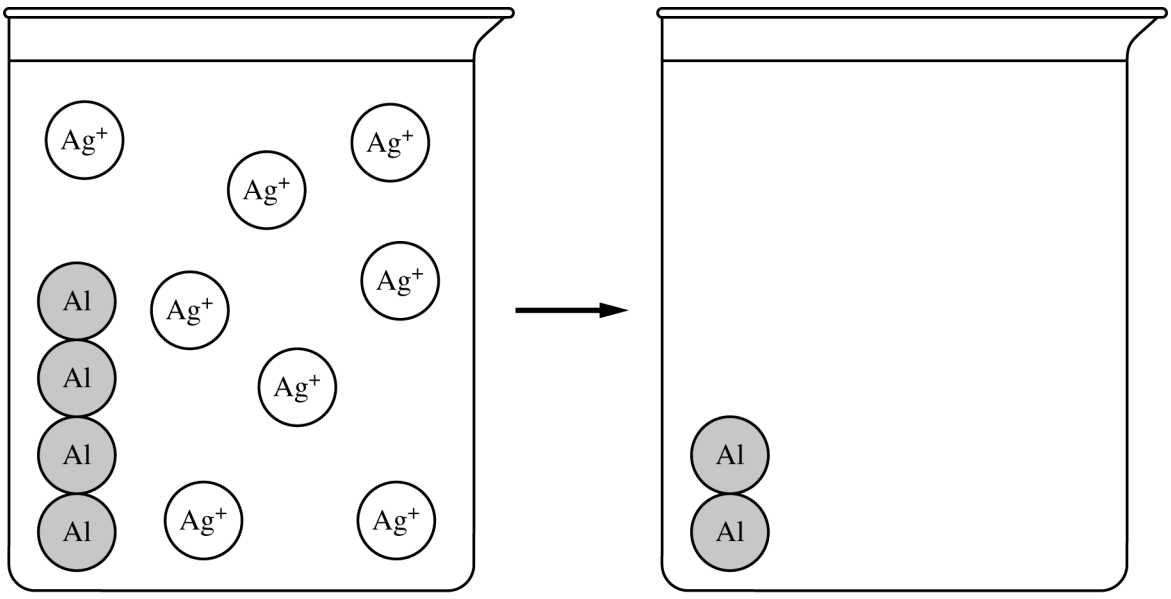
GO ON TO THE NEXT PAGE.

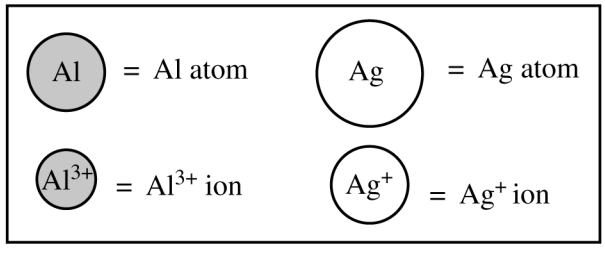
Continue your response to **QUESTION 3** on this page.

After preparing the solution, the student places some of the solution into a beaker and adds a sample of aluminum. The reaction represented by the following equation occurs.

$$Al(s) + 3\ Ag^{+}(aq) \rightarrow Al^{3+}(aq) + 3\ Ag(s)$$

(d) The following diagram gives an incomplete particulate representation of the reaction. The beaker on the left represents the system before the mixture reacts. Complete the drawing on the right to represent the system after the reaction has occurred. Be sure to include 1) the correct type and number of particles based on the number shown on the left and 2) the relative spacing to depict the appropriate phases.





The student finds the standard reduction potentials given in the table, which are related to the reaction that occurs.

Half-Reaction	$E°$
$Ag^{+}(aq) + e^{-} \rightarrow Ag(s)$	0.80 V
$Al^{3+}(aq) + 3\ e^{-} \rightarrow Al(s)$	−1.66 V

GO ON TO THE NEXT PAGE.

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

(e) Using the standard reduction potentials, calculate the value of $E°$ for the reaction.

(f) Based on the value of $E°$, would the standard free energy change of the reaction under standard conditions, $\Delta G°$, be positive, negative, or zero? Justify your answer.

(g) Once the reaction appears to stop progressing, would the change in free energy, ΔG, be positive, negative, or zero? Justify your answer.

GO ON TO THE NEXT PAGE.

Question 3: Long Answer — 10 points

(a) For a correct electron configuration: **1 point**

Accept one of the following:

- $1s^2 2s^2 2p^6 3s^2 3p^1$
- [Ne] $3s^2 3p^1$

(b) For a correct explanation: **1 point**

The highest occupied electron shell (n=3) of Al *is at a greater average distance from the nucleus than the highest occupied electron shell (n=2) of* Al^{3+}.

(c) For the correct steps to dissolve the solute in water (steps may be consolidated): **1 point**

2. Partially fill the volumetric flask with some distilled water

3. Add the weighed $AgNO_3(s)$ *to the volumetric flask*

4. Swirl to dissolve the solid

For the correct step to ensure quantitative dilution: **1 point**

*5. After the solid is dissolved, fill the flask to the calibration (*200.00 mL*) mark and mix.*

Total for part (c) 2 points

(d) For a drawing that shows product formation and indicates the conservation of matter: **1 point**

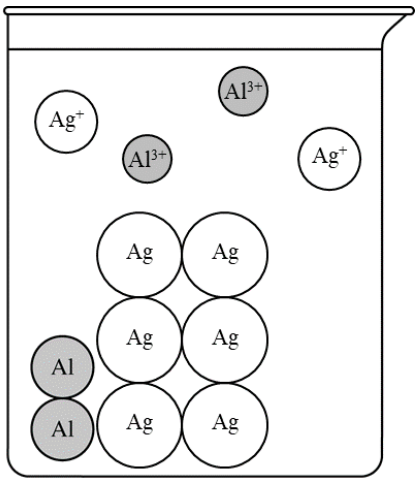
4 Al *and* 8 Ag *particles in the beaker on right (see sample drawing below)*

For a drawing that shows product formation and conservation of charge: **1 point**

2 Ag^+ *ions and* 2 Al^{3+} *ions in the beaker on the right (see sample drawing below)*

For a drawing that shows product formation and correct phases of matter for all species: **1 point**

6 Ag *atoms that are solid and* 2 Al^{3+} *ions that are aqueous in the beaker on the right*



Total for part (d) 3 points

(e) For the correct calculated value: **1 point**

Accept one of the following:

- $E° = 0.80\ \text{V} + 1.66\ \text{V} = 2.46\ \text{V}$
- $E^\circ_{cell} = E^\circ_{red} - E^\circ_{ox} = 0.80\ \text{V} - (-1.66\ \text{V}) = 2.46\ \text{V}$

(f) For the correct answer and a valid justification: **1 point**

Negative. The reaction has a positive value of $E°$, indicating that it is thermodynamically favorable and would therefore have a negative value of $\Delta G°$. ($\Delta G° = -nFE°$)

(g) For the correct answer and a valid justification: **1 point**

Accept one of the following:

- *Zero. The observation that the reaction stops progressing implies that $E_{cell} = 0$, indicating that there is no longer a driving force for the reaction.*
- *Zero. The observation that reaction stops progressing implies that equilibrium is established, and $\Delta G = 0$ at equilibrium.*

Total for question 3 10 points