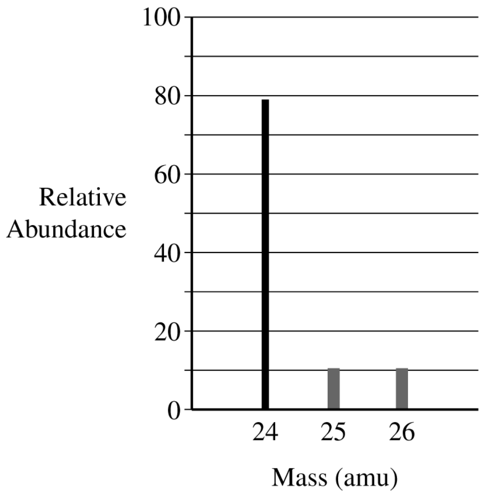
Question 1: Long Answer — 10 points

A (i) For the correct plotted lines: **Point 01**

The abundance for the two lines should be between 10 and 11.



(ii) For the correct answer: **Point 02**

Magnesium-26 has one more neutron than magnesium-25 does.

B (i) For a correct explanation: **Point 03**

The charge on the sodium ion is less than the charge on the magnesium ion. A smaller charge results in a weaker Coulombic attraction between Na^+ *and water.*

(ii) For a correct explanation: **Point 04**

The Na^+ *ion is larger than the* Mg^{2+} *ion, so the distance between the* Na^+ *and the oxygen on the water molecule will be greater. As distance increases, Coulombic attraction decreases.*

C For the correct calculated value: **Point 05**

$$\text{pOH} = -\log(2.80 \times 10^{-4}) = 3.553$$

$$\text{pH} = 14 - \text{pOH} = 14 - 3.553 = 10.447$$

D For the correct calculated value: **Point 06**

$$M_1V_1 = M_2V_2$$

$$M_2 = \frac{(1.85 \times 10^{-3}\,M)(0.03500\text{ L})}{(0.03500\text{ L} + 0.05000\text{ L})} = 7.62 \times 10^{-4}\ M$$

E	(i) For the correct expression: $K_{sp} = [Mg^{2+}][OH^-]^2$	**Point 07**
	(ii) For the correct calculated value, consistent with part D and part E (i): $Q = [Mg^{2+}][OH^-]^2 = (7.62 \times 10^{-4})(1.65 \times 10^{-4})^2 = 2.07 \times 10^{-11}$	**Point 08**
	(iii) For the correct prediction and justification, consistent with part E (ii). Examples of acceptable responses may include the following: • *$Q > K_{sp}$, so a precipitate will form.* • *The concentration of the ions in solution (represented by Q) is greater than that of a saturated solution, so a precipitate will form.*	**Point 09**
F	For the correct answer and justification: *Decrease. The* H^+ *from* $HNO_3(aq)$ *will react with* OH^-*, decreasing* $[OH^-]$ *and causing* $Q < K_{sp}$*. As a result, more* $Mg(OH)_2(s)$ *will dissolve until equilibrium is reestablished, resulting in less* $Mg(OH)_2(s)$.	**Point 10**

Question 6: Short Answer — 4 points

A For the correct equation (state symbols not required): **Point 01**

$$Al(s) \rightarrow Al^{3+}(aq) + 3\,e^-$$

B For the correct balanced net ionic equation (state symbols not required): **Point 02**

$$2\,Al(s) + 3\,Zn^{2+}(aq) \rightarrow 2\,Al^{3+}(aq) + 3\,Zn(s)$$

C For the correct answer and a valid justification that correctly compares the masses of Al and Zn based on their molar masses and the stoichiometry of the balanced equation. **Point 03**

Examples of acceptable responses may include the following:

- Zn *experiences a greater change in mass. Assuming the entire* Al *anode reacts:*

  $$50.0\text{ g Al} \times \frac{1\text{ mol Al}}{26.98\text{ g Al}} \times \frac{3\text{ mol Zn}}{2\text{ mol Al}} \times \frac{65.38\text{ g Zn}}{1\text{ mol Zn}} = 182\text{ g Zn}$$

- Zn *experiences a greater change in mass.*

  $$1\text{ mol}_{rxn} \times \frac{3\text{ mol Zn}}{1\text{ mol}_{rxn}} \times \frac{65.38\text{ g Zn}}{1\text{ mol Zn}} = 196.1\text{ g Zn}$$

  $$1\text{ mol}_{rxn} \times \frac{2\text{ mol Al}}{1\text{ mol}_{rxn}} \times \frac{26.98\text{ g Al}}{1\text{ mol Al}} = 53.96\text{ g Al}$$

  Thus, for however many moles of reaction that proceed, the mass of Zn *produced will be greater than the mass of* Al *consumed.*

- Zn *experiences a greater change in mass. As the reaction proceeds, three moles of* Zn *are used for every two moles of* Al. *Thus, for every* 196 g *of* Zn *that are produced,* 54 g *of* Al *are consumed.*

D For the correct calculated value. **Point 04**

Examples of acceptable responses may include the following:

- $E^\circ_{cell} = 1.50\text{ V} + 0.76\text{ V} = 2.26\text{ V}$

- $$\begin{array}{lr} Au^{3+}(aq) + 3\,e^- \rightarrow Au(s) & +1.50\text{ V} \\ \underline{Zn(s) \rightarrow Zn^{2+}(aq) + 2\,e^-} & \underline{+\,0.76\text{ V}} \\ & E^\circ_{cell} = 2.26\text{ V} \end{array}$$

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**

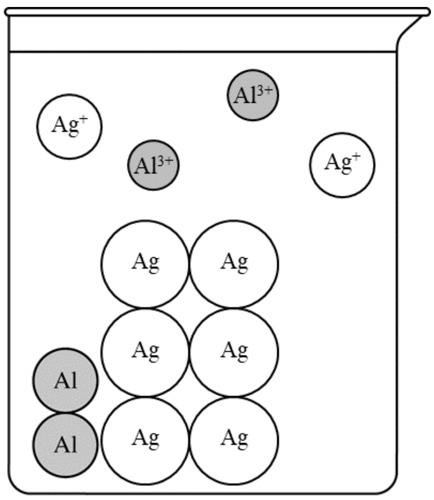
4 Al *and* 8 Ag *particles in the beaker on right (see sample drawing below)*

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: Accept one of the following: • $E° = 0.80\text{ V} + 1.66\text{ V} = 2.46\text{ V}$ • $E^{\circ}_{cell} = E^{\circ}_{red} - E^{\circ}_{ox} = 0.80\text{ V} - (-1.66\text{ V}) = 2.46\text{ V}$	**1 point**
(f)	For the correct answer and a valid justification: *Negative. The reaction has a positive value of* $E°$*, indicating that it is thermodynamically favorable and would therefore have a negative value of* $\Delta G°$*. (*$\Delta G° = -nFE°$*)*	**1 point**
(g)	For the correct answer and a valid justification: 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.*	**1 point**
	Total for question 3	**10 points**