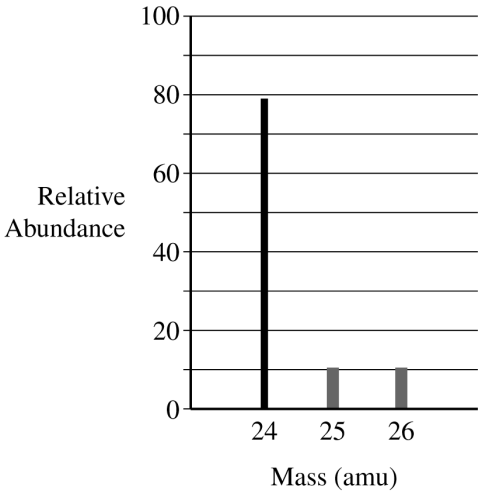
Question 1: Long Answer — 10 points

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: **Point 07**

$K_{sp} = [Mg^{2+}][OH^-]^2$

(ii) For the correct calculated value, consistent with part D and part E (i): **Point 08**

$Q = [Mg^{2+}][OH^-]^2 = (7.62 \times 10^{-4})(1.65 \times 10^{-4})^2 = 2.07 \times 10^{-11}$

(iii) For the correct prediction and justification, consistent with part E (ii). **Point 09**

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.*

F For the correct answer and justification: **Point 10**

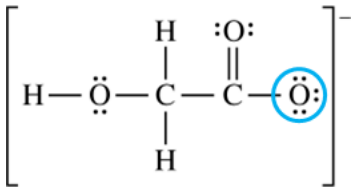
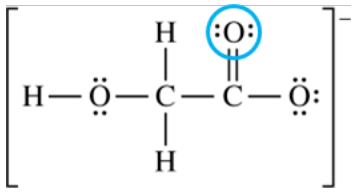
Decrease. The H^+ *from* $HNO_3(aq)$ *will react with* OH^-*, decreasing* $[OH^-]$ *and causing* $Q < K_{sp}$*. As a result, more* $Mg(OH)_2(s)$ *will dissolve until equilibrium is reestablished, resulting in less* $Mg(OH)_2(s)$.

Question 7: Short Answer — 4 points

A — **Point 01**

For a correct circled atom.

Accept one of the following:

- 
- 

(Because of resonance, the two $C-O$ *bonds on the right are equivalent.)*

B — (i) For the correct calculated value: **Point 02**

$$K_b = \frac{[HC_2H_3O_3][OH^-]}{[C_2H_3O_3^-]} = \frac{(1.3\times10^{-5})(1.3\times10^{-5})}{(2.5-1.3\times10^{-5})} \approx \frac{(1.3\times10^{-5})^2}{(2.5)} = 6.8\times10^{-11}$$

(ii) For the correct calculated value, consistent with part B (i): **Point 03**

$$K_a = \frac{K_w}{K_b} = \frac{1.0\times10^{-14}}{6.8\times10^{-11}} = 1.5\times10^{-4}$$

C — For the correct answer and a valid justification: **Point 04**

Agree. H_3O^+ *is consumed in step 1 and regenerated in step 2, which is consistent with the behavior of a catalyst.*

Question 5: Short Answer — 4 points

(a) (i) For the correct calculated value: **1 point**

$$n = \frac{PV}{RT} = \frac{(7.45\text{ atm})(6.00\text{ L})}{(0.08206\frac{\text{L·atm}}{\text{mol·K}})(296\text{ K})} = 1.84\text{ mol}$$

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

Accept one of the following:

- $\frac{P_1}{T_1} = \frac{P_2}{T_2}$

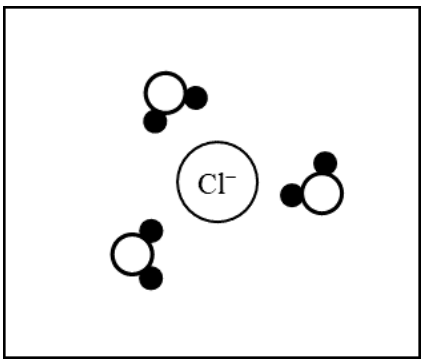
  $P_2 = \frac{(P_1)(T_2)}{T_1} = \frac{(7.45\text{ atm})(271\text{ K})}{296\text{ K}} = 6.82\text{ atm}$

- $P = \frac{nRT}{V} = \frac{(1.84\text{ mol})(0.08206\frac{\text{L·atm}}{\text{mol·K}})(271\text{ K})}{6.00\text{ L}} = 6.82\text{ atm}$

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

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

The drawing should show three water molecules with a hydrogen atom (dark circle) oriented towards the Cl^- *ion.*



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

HNO_2. *The diagram shows most of the molecules in their un-ionized form, indicating a weak acid with a* K_a *value less than 1, which is consistent with* HNO_2.

Total for question 5 **4 points**