2026

AP® Chemistry

Scoring Guidelines

Question 1: Long Answer — 10 points

A (i) For the correct answer — **Point 01**

Examples of acceptable responses may include the following:

- $1s^2 2s^2 2p^6 3s^2 3p^6$
- $[\text{Ne}]\ 3s^2 3p^6$

(ii) For the correct answer, consistent with part A (i) — **Point 02**

Examples of acceptable responses may include the following:

- The K atom. The outermost electron in K is in a shell farther from the nucleus ($n = 4$) than it is for the K^+ ion ($n = 3$).
- The K atom. The K atom has the same nuclear charge as the K^+ ion, but K has one more electron than K^+ has.

B For the correct answer — **Point 03**

Examples of acceptable responses may include the following:

- The temperature stops decreasing when dissolution is complete.
- The temperature starts to increase from its minimum value when dissolution is complete.

C (i) For the correct calculated value reported with the correct number of significant figures (sign not required) — **Point 04**

$q = mc\Delta T$

$q = (97.5\ \text{g} + 6.80\ \text{g})(3.95\ \text{J/(g}\cdot\text{°C)})(21.1\text{°C} - 24.5\text{°C}) = -1400\ \text{J}$

(ii) For the correct calculated value, consistent with part C (i), with a positive sign — **Point 05**

$q_{sys} = -q_{surr} = -(-1400\ \text{J}) = +1400\ \text{J}$

$\frac{+1400\ \text{J}}{0.0912\ \text{mol}} = +15{,}000\ \text{J/mol} = +15\ \text{kJ/mol}$

D For the correct answer and a valid justification — **Point 06**

Less than. Because some heat was transferred from outside the calorimeter, the observed temperature change would be less than expected, so the calculated magnitudes of q and ΔH°_{soln} would be less.

E For the correct answer and a valid justification — **Point 07**

Less than. The molar mass of RbCl is greater than that of KCl, so an equal mass of RbCl contains fewer moles. Fewer moles of solute will result in a smaller magnitude of q and smaller change in temperature.

F (i) For the correct net ionic equation (state symbols not required) **Point 08**

$RbCl(s) \rightleftarrows Rb^+(aq) + Cl^-(aq)$

(ii) For the correct calculated value **Point 09**

$K_{sp} = [Rb^+][Cl^-]$
$57 = (s)(s)$
$s = 7.5\ M$

(iii) For the correct answer and a valid justification **Point 10**

Examples of acceptable responses may include the following:

- Less than. The presence of extra Cl^- ions in the KCl solution will reduce the amount of $RbCl(s)$ that dissolves when equilibrium is reached (due to the common ion effect).
- Less than. Calculating the molar solubility in $1.0\ M\ KCl(aq)$:

$RbCl(s) \rightleftarrows$	$Rb^+(aq)$	+	$Cl^-(aq)$
	0		$1.0\ M$
	$+\ s$		$+\ s$
	s		$1.0 + s$

$K_{sp} = [Rb^+][Cl^-]$
$57 = (s)(1.0 + s) = 1.0s + s^2$
$s = 7.1\ M < 7.5\ M$

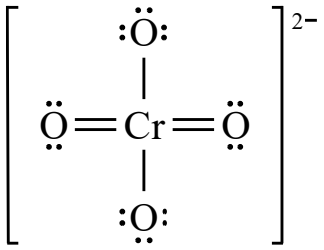
Question 2: Long Answer — 10 points

A (i) For the correct answer — **Point 01**

Tetrahedral

(ii) For a correct diagram — **Point 02**

The diagram should consist of two double bonds and two single bonds between Cr and surrounding O atoms, and the appropriate number of lone pairs on each O atom. See the following sample response.



B (i) For the correct balanced equation (state symbols not required) — **Point 03**

Examples of acceptable responses may include the following:

- $2\ CrO_4^{2-}(aq) + 2\ H^+(aq) \rightleftarrows Cr_2O_7^{2-}(aq) + H_2O(l)$
- $2\ CrO_4^{2-}(aq) + 2\ H_3O^+(aq) \rightleftarrows Cr_2O_7^{2-}(aq) + 3\ H_2O(l)$

(ii) For the correct answer and a valid justification — **Point 04**

No. The oxidation number of Cr is +6 in CrO_4^{2-} and in $Cr_2O_7^{2-}$, thus the reaction is not redox.

C For the correct answer and a valid justification based on the correctly calculated value — **Point 05**

The reaction is thermodynamically unfavorable under standard conditions because $\Delta G°$ is positive.

$$\Delta G° = -nFE° = -\frac{6\ \text{mol}\ e^-}{1\ \text{mol}_{rxn}} \times \frac{96{,}485\ \text{C}}{\text{mol}\ e^-} \times \frac{-1.32\ \text{J}}{1\ \text{C}} \times \frac{1\ \text{kJ}}{1000\ \text{J}} = +764\ \text{kJ/mol}_{rxn}$$

D For the correct calculated value of moles of electrons (may be implicit) — **Point 06**

$$3250\ \text{s} \times \frac{15.0\ \text{C}}{1\ \text{s}} \times \frac{1\ \text{mol}\ e^-}{96{,}485\ \text{C}} = 0.505\ \text{mol}\ e^-$$

For the correct calculated mass of chromium — **Point 07**

$$0.505\ \text{mol}\ e^- \times \frac{1\ \text{mol Cr}}{6\ \text{mol}\ e^-} \times \frac{52.00\ \text{g}}{1\ \text{mol}} = 4.38\ \text{g}$$

E For the correct answer **Point 08**

The reaction has a constant half-life of 20 minutes.

F For the correct calculated value **Point 09**

Examples of acceptable responses may include the following:

- Using the integrated rate law

$$k = \frac{\ln[Cr_2O_7^{2-}]_t - \ln[Cr_2O_7^{2-}]_0}{-t}$$

$$k = \frac{(-1.20 - (-0.70))}{-15 \text{ min}} = 0.033 \text{ min}^{-1}$$

- Using the slope from the $\ln[Cr_2O_7^{2-}]$ vs. time graph

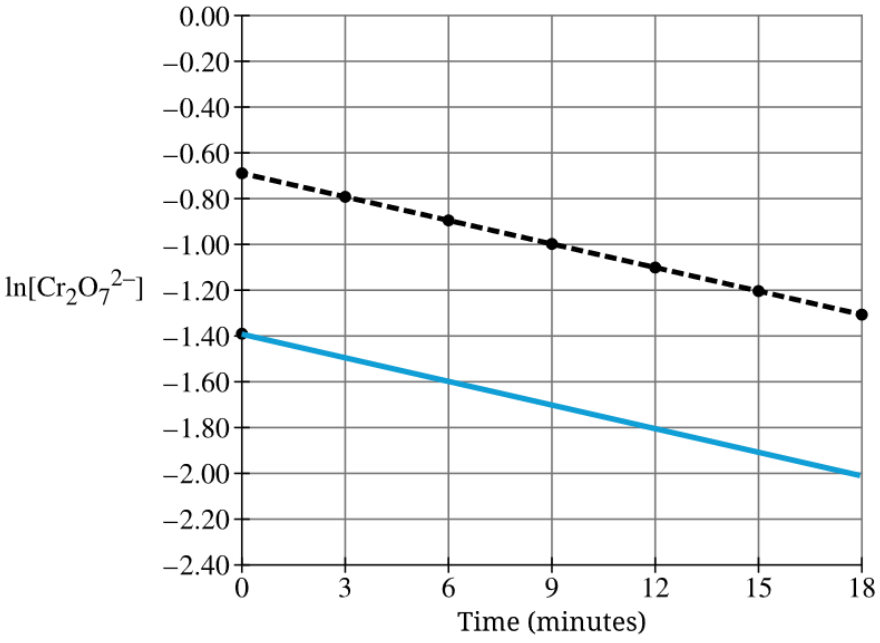
$$k = -slope = \frac{-(-1.00 - (-0.80))}{(9 \text{ min} - 3 \text{ min})} = \frac{0.20}{6} = 0.033 \text{ min}^{-1}$$

- Using the half-life from the $[Cr_2O_7^{2-}]$ vs. time graph

$$k = \frac{\ln 2}{t_{1/2}} = \frac{0.693}{20. \text{ min}} = 0.035 \text{ min}^{-1}$$

G For a correct drawing **Point 10**

The graph should start at $(0, -1.40)$ and be parallel to the line from the original experiment. See the following sample response.



Question 3: Long Answer — 10 points

A — For the correct answer — **Point 01**

Examples of acceptable answers may include the following:

- $\underset{\text{acid}}{HNO_2}$ and $\underset{\text{base}}{NO_2^-}$
- $\underset{\text{base}}{H_2O}$ and $\underset{\text{acid}}{H_3O^+}$

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

$$pH = -\log[H_3O^+]$$
$$[H_3O^+] = 10^{-pH} = 10^{-2.09} = 0.0081\ M$$

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

Examples of acceptable responses may include the following:

- $[HNO_2] = 0.125\ M - 0.0081\ M = 0.117\ M$
- $5.6 \times 10^{-4} = \dfrac{(0.0081)^2}{x}$

  $x = 0.117\ M \approx 0.12\ M$

C — (i) For the correct calculated value — **Point 04**

$$K_a = \frac{(0.0109)^2}{0.114} = 1.04 \times 10^{-3}$$

(ii) For the correct answer, consistent with part C (i) — **Point 05**

Endothermic. The K_a increases with a higher temperature, which is consistent with an endothermic reaction.

D — For the correct answer — **Point 06**

$pH = 8.0$ (acceptable range: $7 < pH \leq 10$)

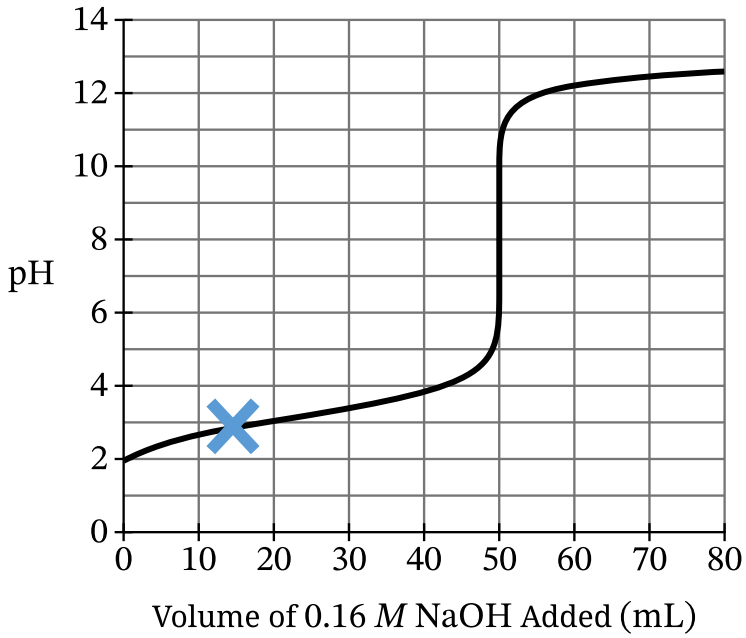
E — For the correct calculated value, consistent with part D — **Point 07**

$$0.050\ \text{L NaOH} \times \frac{0.16\ \text{mol NaOH}}{1\ \text{L}} \times \frac{1\ \text{mol } HNO_2}{1\ \text{mol NaOH}} = 0.0080\ \text{mol } HNO_2$$

$$\frac{0.0080\ \text{mol } HNO_2}{0.0350\ \text{L}} = 0.23\ M\ HNO_2$$

F For a correct drawing **Point 08**

The X should be drawn before $25\ \text{mL}$. See the following sample response.



G For the correct calculated value **Point 09**

$HNO_2(aq) + H_2O(l) \rightleftarrows H_3O^+(aq) + NO_2^-(aq)$ $\quad K_a$

$H_3O^+(aq) + OH^-(aq) \rightleftarrows H_2O(l) + H_2O(l)$ $\quad \frac{1}{K_w}$

$$K_2 = K_a \times \frac{1}{K_w} = \frac{K_a}{K_w} = \frac{5.6 \times 10^{-4}}{1.0 \times 10^{-14}} = 5.6 \times 10^{10}$$

H For the correct answer and a valid justification **Point 10**

Examples of acceptable responses may include the following:

- Disagree. The color change for this indicator occurs in the pH range $3.1 - 4.4$, but the titration data suggest the equivalence point is in the pH range $8 - 9$.
- Disagree. Thymol blue would be a better indicator because the color change would occur at the equivalence point.

Question 4: Short Answer — 4 points

A For a correct explanation — **Point 01**

Each $P-P$ single bond in P_4 is longer than the $P{\equiv}P$ triple bond in P_2.

B For the correct calculated partial pressure of P_4 — **Point 02**

Examples of acceptable responses may include the following:

- $$\begin{array}{lccc} & P_4(g) & \rightleftarrows & 2\,P_2(g) \\ \text{I} & 0.470\text{ atm} & & 0 \\ \text{C} & -x & & +2x \\ \hline \text{E} & 0.470 - x & & 0.630\text{ atm} \end{array}$$
  $x = \frac{1}{2}(0.630\text{ atm}) = 0.315\text{ atm}$
  $P_{P_4} = 0.470\text{ atm} - 0.315\text{ atm} = 0.155\text{ atm}$
- $P_{P_4} = 0.470\text{ atm} - \frac{1}{2}(0.630\text{ atm}) = 0.155\text{ atm}$

For the correct calculated value of K_p, consistent with the calculated value of P_{P_4} — **Point 03**

$$K_p = \frac{(P_{P_2})^2}{P_{P_4}} = \frac{(0.630)^2}{0.155} = 2.56$$

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

Examples of acceptable responses may include the following:

- Agree. Because 2 moles of gaseous product are being generated from 1 mole of gaseous reactant, ΔS°_{rxn} is positive. Because ΔG°_{rxn} is only negative when temperature is sufficiently elevated, ΔH°_{rxn} must also be positive, so the reaction is endothermic.
- Agree. Because the reaction is favorable only at high temperatures, ΔG°_{rxn} is only negative when temperature is sufficiently elevated, so both ΔH°_{rxn} and ΔS°_{rxn} must be positive, in accordance with $\Delta G^\circ_{rxn} = \Delta H^\circ_{rxn} - T\Delta S^\circ_{rxn}$.

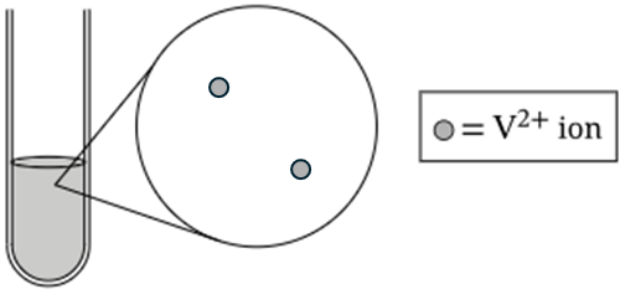
Question 5: Short Answer — 4 points

A	For the correct answer and a valid justification The C–F bond. The difference in electronegativity between C and F is greater than the difference between C and Br and the difference between C and Cl.	**Point 01**
B	For a correct explanation The Br and Cl atoms have larger electron clouds than F atoms do, so the valence shell electrons of Br and Cl cause more repulsion, leading to a larger bond angle.	**Point 02**
C	(i) For the correct answer CBr_4 : London dispersion forces (LDF) $CBrClF_2$: London dispersion forces (LDF) and dipole-dipole forces	**Point 03**
	(ii) For a correct explanation CBr_4 has a much larger and more polarizable electron cloud than $CBrClF_2$ does, resulting in London dispersion forces among CBr_4 molecules that are stronger than the combined London dispersion and dipole-dipole forces experienced among $CBrClF_2$ molecules.	**Point 04**

Question 6: Short Answer — 4 points

A For a correct drawing **Point 01**

Two particles should be drawn in the circle.



Absorbance = 0.08

B (i) For the correct answer **Point 02**

Examples of acceptable responses may include the following:

- Using the Beer-Lambert Law ($A = \varepsilon bc$), choosing a point from the graph, and assuming a 1.0 cm path length

  $$\varepsilon = \frac{A}{bc} = \frac{0.20}{(1.0\text{ cm})(0.050\ M)} = 4.0\text{ cm}^{-1}\ M^{-1}$$

  $$c = \frac{A}{\varepsilon b} = \frac{0.22}{(4.0\text{ cm}^{-1}M^{-1})(1.0\text{ cm})} = 0.055\ M$$

- Using the slope of the line, by choosing two points from the graph

  $$slope = \frac{(0.36 - 0)}{(0.090 - 0)} = 4.0$$

  $$A = 4.0c$$

  $$c = \frac{A}{4.0} = \frac{0.22}{4.0} = 0.055\ M$$

- Reading from the graph
  $0.055\ M$ (acceptable range: $0.053–0.057\ M$)

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

$$M_1V_1 = M_2V_2$$

$$M_1 = \frac{M_2V_2}{V_1} = \frac{(0.055\ M)(25.0\text{ mL})}{3.00\text{ mL}} = 0.46\ M$$

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

Agree. If the student added too much distilled water to the volumetric flask, the volume of solution would be greater, which would cause the observed absorbance (and molarity) of the diluted solution to be too low, resulting in a lower calculated molarity of the undiluted solution.

Question 7: Short Answer — 4 points

A For the correct calculated value — **Point 01**

Examples of acceptable responses may include the following:

- $\Delta H^\circ_{rxn} = \Sigma \Delta H^\circ_{f\ products} - \Sigma \Delta H^\circ_{f\ reactants}$

  $-828\ \text{kJ/mol}_{rxn} = 2x - 0$

  $x = -414\ \text{kJ/mol}$

- $\Delta H^\circ_f = \dfrac{-828\ \text{kJ}}{1\ \text{mol}_{rxn}} \times \dfrac{1\ \text{mol}_{rxn}}{2\ \text{mol Na}_2\text{O}} = -414\ \text{kJ/mol}$

B For a correct determination of the limiting reactant (may be implicit) — **Point 02**

Examples of acceptable responses may include the following:

- $18.4\ \text{g Na} \times \dfrac{1\ \text{mol Na}}{22.99\ \text{g Na}} \times \dfrac{1\ \text{mol}_{rxn}}{4\ \text{mol Na}} = 0.200\ \text{mol}_{rxn}$

  $12.8\ \text{g O}_2 \times \dfrac{1\ \text{mol O}_2}{32.00\ \text{g O}_2} \times \dfrac{1\ \text{mol}_{rxn}}{1\ \text{mol O}_2} = 0.400\ \text{mol}_{rxn}$

- $18.4\ \text{g Na} \times \dfrac{1\ \text{mol Na}}{22.99\ \text{g Na}} \times \dfrac{2\ \text{mol Na}_2\text{O}}{4\ \text{mol Na}} = 0.400\ \text{mol Na}_2\text{O}$

  $12.8\ \text{g O}_2 \times \dfrac{1\ \text{mol O}_2}{32.00\ \text{g O}_2} \times \dfrac{2\ \text{mol Na}_2\text{O}}{1\ \text{mol O}_2} = 0.800\ \text{mol Na}_2\text{O}$

- $18.4\ \text{g Na} \times \dfrac{1\ \text{mol Na}}{22.99\ \text{g Na}} = 0.800\ \text{mol Na}$

  $12.8\ \text{g O}_2 \times \dfrac{1\ \text{mol O}_2}{32.00\ \text{g O}_2} = 0.400\ \text{mol O}_2$

  $\dfrac{0.800\ \text{mol Na}}{0.400\ \text{mol O}_2} < \dfrac{4\ \text{mol Na}}{1\ \text{mol O}_2}$, so Na is the limiting reactant.

For the correct calculated amount of energy, consistent with the moles of limiting reactant — **Point 03**

Examples of acceptable responses may include the following:

- $0.200\ \text{mol}_{rxn} \times \dfrac{-828\ \text{kJ}}{1\ \text{mol}_{rxn}} = -166\ \text{kJ}$, so 166 kJ are released.

- $0.400\ \text{mol Na}_2\text{O} \times \dfrac{-828\ \text{kJ}}{2\ \text{mol Na}_2\text{O}} = -166\ \text{kJ}$

- $0.800\ \text{mol Na} \times \dfrac{1\ \text{mol}_{rxn}}{4\ \text{mol Na}} \times \dfrac{-828\ \text{kJ}}{1\ \text{mol}_{rxn}} = -166\ \text{kJ}$

C For a correct explanation — **Point 04**

Rb^+ has a larger ionic radius than Na^+, resulting in a greater separation between the centers of the ions and weaker Coulombic attractions in Rb_2O than in Na_2O.