Past-paper walk-through

Stoichiometry ▪ 4.5

eXercise

Questions in this set

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Reading the mark scheme

- **B1** a mark that stands on its own – the point is either made or not.
- **M1** a *method* mark: the right approach, even if the number is wrong.
- **A1** an *answer* mark, and it usually needs its M mark first.
- **C1** a working mark on the way to the answer.
- // separates answers the examiner accepts equally.
- **ecf** = error carried forward: a later part is marked on your own earlier answer.
- **owtte** = "or words to that effect" – the wording need not match.

Question 7

2026 ▪ Q7

The following information applies to parts A and B.
Sodium metal reacts with oxygen gas according to Equation 1.

Equation 1: $4\,\mathrm{Na}(s) + \mathrm{O_2}(g) \rightarrow 2\,\mathrm{Na_2O}(s) \qquad \Delta H^\circ_{rxn} = -828\ \mathrm{kJ/mol}_{rxn}$

Standard enthalpies of formation are provided in Table 1.
| Substance | ΔH°_f (kJ/mol) | |—|—| | $\mathrm{Na}(s)$ | 0 | | $\mathrm{O_2}(g)$ | 0 | | $\mathrm{Na_2O}(s)$ | ? |
(a) Based on the information given, **calculate** the value of ΔH°_f for $\mathrm{Na_2O}(s)$. Show the work that leads to your answer.
(b) An 18.4 g sample of $\mathrm{Na}(s)$ reacts with 12.8 g of $\mathrm{O_2}(g)$ according to Equation 1. **Calculate** the total amount of heat, in kilojoules, released during this process. Show the work that leads to your answer.

Question 7

(c) Lattice enthalpy can be defined as the energy required to separate an ionic crystal into gaseous ions. $Rb_2O(s)$ and $Na_2O(s)$ have similar crystal structures, and their lattice enthalpies are given in Table 2.
| Compound | Lattice Enthalpy (kJ/mol) | |—|—| | $Na_2O(s)$ | 2481 | | $Rb_2O(s)$ | 2163 |
Using Coulomb's law, **explain** why the lattice enthalpy of $Rb_2O(s)$ is smaller than that of $Na_2O(s)$.

Table 2

Compound	Lattice Enthalpy (kJ/mol)
$Na_2O\,(s)$	2481
$Rb_2O\,(s)$	2163

Table 1

Substance	ΔH_f° (kJ/mol)
$Na(s)$	0
$O_2(g)$	0
$Na_2O(s)$	?

Question 1

2025 ▪ Q1

Answer the following questions about magnesium.

(a) An incomplete mass spectrum for magnesium is shown in the diagram.

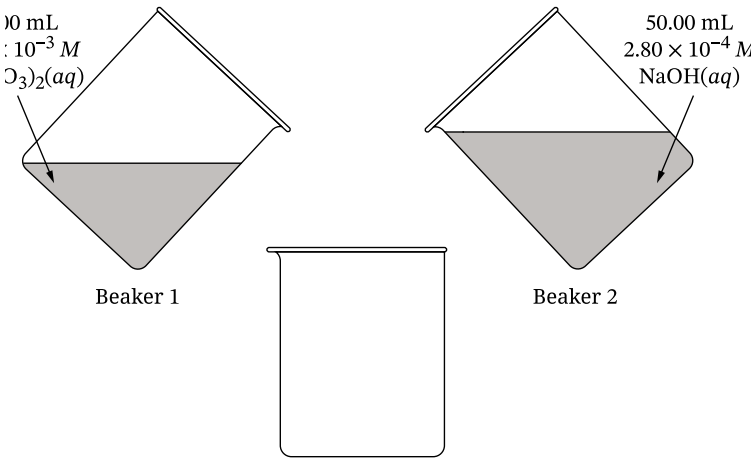
[Bar graph titled "Relative Abundance" vs. "Mass (amu)"; y-axis from 0 to 100 in increments of 20; x-axis shows tick marks at 24, 25, 26; a single thick vertical bar is drawn at mass 24 reaching a relative abundance of about 79.]

The percent abundance of magnesium-24 is 79%. The percent abundances of the other two natural isotopes of magnesium, magnesium-25 and magnesium-26, are approximately equal.

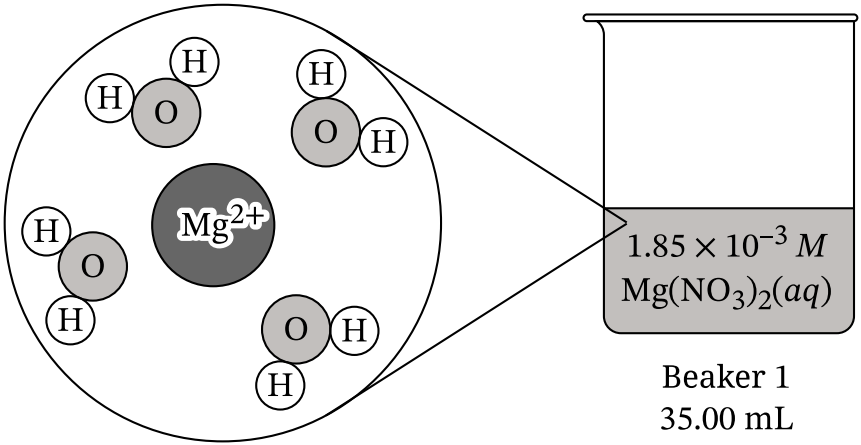
(a)(i) Complete the mass spectrum in part A by drawing thick lines in the appropriate locations to represent the percent abundance of magnesium-25 and magnesium-26.

(a)(ii) Describe the difference in atomic structure that accounts for the difference in mass between magnesium-25 and magnesium-26.

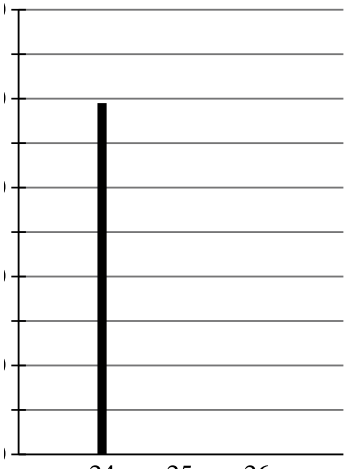
Question 1


)0 mL
: 10^{-3} M
$O_3)_2(aq)$
Beaker 1
50.00 mL
2.80×10^{-4} M
NaOH(aq)
Beaker 2

Question 1



Question 1



Question 1

2025 ▪ Q1

Answer the following questions about magnesium.

(b) A student prepares a 1.85×10^{-3} *M* solution of $Mg(NO_3)_2(aq)$ in beaker 1 and a 2.80×10^{-4} *M* solution of $NaOH(aq)$ in beaker 2, as shown.

[Particle diagram: a magnesium ion, Mg^{2+}, at the center surrounded by six water molecules (H2O), each oriented with its oxygen atom pointing toward the central Mg^{2+} ion and its two hydrogen atoms pointing outward.]

[Beaker 1: labeled "1.85×10^{-3} *M* $Mg(NO_3)_2(aq)$", "Beaker 1", "35.00 mL".]

[Beaker 2: labeled "2.80×10^{-4} *M* $NaOH(aq)$", "Beaker 2", "50.00 mL".]

The particle diagram shown represents a magnesium ion, Mg^{2+}, in beaker 1. A sodium ion, Na^+, in beaker 2 has a weaker attraction to water than the Mg^{2+} does. Explain this phenomenon using Coulomb's law and each of the following.

(b)(i) The relative charge of the ions

Question 1

(b)(ii) The relative radii of the ions

Question 1

2025 ▪ Q1

Answer the following questions about magnesium.

(c) Calculate the pH of the solution in beaker 2.

Question 1

2025 ▪ Q1

Answer the following questions about magnesium.

(d) A student combines 35.00 mL of 1.85×10^{-3} *M* $Mg(NO_3)_2(aq)$ with 50.00 mL of 2.80×10^{-4} *M* $NaOH(aq)$, as shown in the diagram. Calculate $\left[Mg^{2+}\right]$ after the two solutions are combined but before any reaction takes place. (Assume that volumes are additive.)

[Diagram of two conical/Erlenmeyer flasks being poured into an empty Beaker 3. Left flask: "35.00 mL", "1.85×10^{-3} *M*", "$Mg(NO_3)_2(aq)$", labeled "Beaker 1". Right flask: "50.00 mL", "2.80×10^{-4} *M*", "$NaOH(aq)$", labeled "Beaker 2". Both flasks have an arrow pointing down into the empty "Beaker 3" between them.]

Question 1

2025 ▪ Q1

Answer the following questions about magnesium.

(e) The dissolution of magnesium hydroxide is represented by the following equation.

$$\mathrm{Mg(OH)_2}(s) \rightleftharpoons \mathrm{Mg^{2+}}(aq) + 2\,\mathrm{OH^-}(aq) \qquad K_{sp} = 5.61 \times 10^{-12}$$

(e)(i) Write the expression for the solubility product constant, K_{sp}.

(e)(ii) After the two solutions are combined in beaker 3 as described in part D, but before any reaction takes place, $\left[\mathrm{OH^-}\right] = 1.65 \times 10^{-4}$ M. Using your answer to part D, calculate the value of the reaction quotient, Q.

(e)(iii) Using the reaction quotient, Q, predict whether a precipitate should form as the mixture in beaker 3 approaches equilibrium. Justify your answer.

Question 1

2025 ▪ Q1

Answer the following questions about magnesium.

(f) In a separate experiment, the student adds $HNO_3(aq)$ to decrease the pH of a saturated solution containing undissolved $Mg(OH)_2(s)$. Does the amount of undissolved $Mg(OH)_2(s)$ increase, decrease, or remain the same as the $HNO_3(aq)$ is added? Justify your answer.

Solution 1

(a)

Mark scheme

- No separate response required — this is the context/stem describing the incomplete mass spectrum (magnesium-24 at 79% abundance) that parts (i) and (ii) below refer to.

(a)(i)

Mark scheme

- Draw two vertical bars at masses 25 and 26, each reaching a relative abundance of approximately 10 to 11 (since Mg-25 and Mg-26 together make up the remaining ~21% and are approximately equal, so roughly 10–11% each).

Solution 1

(a)(ii)

Mark scheme

- Magnesium-26 has one more neutron than magnesium-25 does (Mg-25 has 13 neutrons, Mg-26 has 14 neutrons; both isotopes have 12 protons, since they are the same element).

Solution 1

(b)

Mark scheme

- No separate response required — this is the context/stem introducing the 1.85×10^{-3} *M* $Mg(NO_3)_2(aq)$ and 2.80×10^{-4} *M* NaOH(aq) solutions (with a particle diagram of hydrated Mg^{2+}) that parts (i) and (ii) below refer to.

(b)(i)

Mark scheme

- The charge on the sodium ion (Na^+, $+1$) is less than the charge on the magnesium ion (Mg^{2+}, $+2$). A smaller charge results in a weaker Coulombic attraction between Na^+ and water.

Solution 1

(b)(ii)

Mark scheme

- The Na^+ ion is larger (has a greater ionic radius) than the Mg^{2+} ion, so the distance between Na^+ and the oxygen atom of the water molecule will be greater. As distance increases, Coulombic attraction decreases, so Na^+ is less strongly attracted to water than Mg^{2+}.

Solution 1

(c)

Mark scheme

- $\mathrm{pOH} = -\log(2.80 \times 10^{-4}) = 3.553.$ $\mathrm{pH} = 14 - \mathrm{pOH} = 14 - 3.553 = 10.447.$

Solution 1

(d)

Mark scheme

- Using $M_1V_1 = M_2V_2$: $M_2 = \dfrac{(1.85 \times 10^{-3}\ M)(0.03500\ \text{L})}{0.03500\ \text{L} + 0.05000\ \text{L}} = 7.62 \times 10^{-4}\ M.$
  So $[\text{Mg}^{2+}]$ after combining but before reaction is $7.62 \times 10^{-4}\ M$.

Solution 1

(e)

Mark scheme

- No separate response required — this is the context/stem giving the $Mg(OH)_2$ dissolution equilibrium and $K_{sp} = 5.61 \times 10^{-12}$ that parts (i)–(iii) below refer to.

(e)(i)

Mark scheme

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

Solution 1

(e)(ii)

Mark scheme

- Using $[Mg^{2+}] = 7.62 \times 10^{-4}$ M (from part D) and $[OH^-] = 1.65 \times 10^{-4}$ M (given): $Q = [Mg^{2+}][OH^-]^2 = (7.62 \times 10^{-4})(1.65 \times 10^{-4})^2 = 2.07 \times 10^{-11}$.

(e)(iii)

Mark scheme

- Q $(2.07 \times 10^{-11}) > K_{sp}$ (5.61×10^{-12}), so a precipitate should form. Equivalently: the concentration of ions in solution (represented by Q) is greater than that of a saturated solution, so a precipitate will form.

Solution 1

(f)

Mark scheme

- The amount of undissolved $Mg(OH)_2(s)$ will decrease. The H^+ from $HNO_3(aq)$ reacts 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 undissolved $Mg(OH)_2(s)$.

Question 2

2025 ▪ Q2

Answer the following questions about ascorbic acid (vitamin C).

(a) A student combusts a sample of ascorbic acid, $C_xH_yO_x$, to determine its chemical composition. The only products of the reaction are 0.2400 mol of CO_2 and 2.883 g of H_2O.

(a)(i) Calculate the number of moles of H_2O produced.

(a)(ii) The mole ratio of carbon (C) to oxygen (O) is 1:1 in ascorbic acid. Based on this information and your answer to part A (i), determine the empirical formula of ascorbic acid.

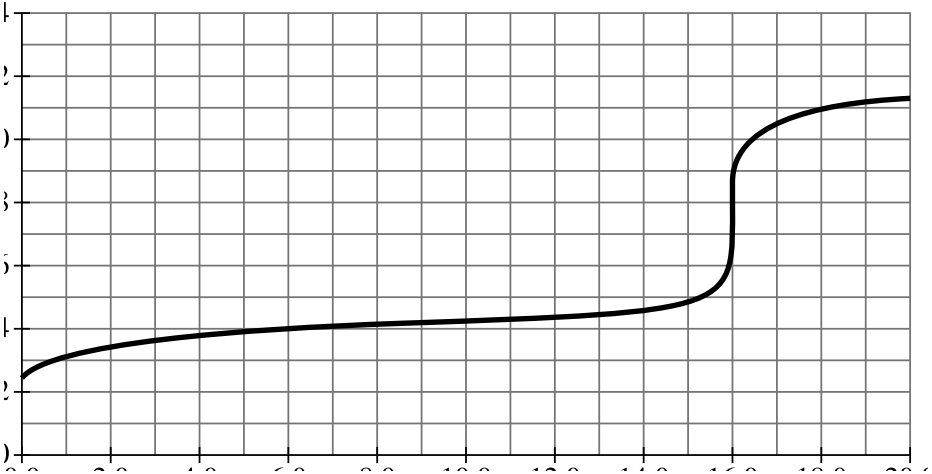
Question 2

Trial	[HAsc] (M)	$[I_3^-](M)$	Initial Rate of DHAsc Formation (M/s)
1	0.450	1.200	2.457×10^{-4}
2	0.450	0.600	1.229×10^{-4}
3	0.900	1.200	4.914×10^{-4}

i. The rate law for the reaction is $rate = k[\text{HAsc}][I_3^-]$. Explain how the data in the table support the conclusion that the reaction is first order with respect to $[\text{HAsc}]$.

ii. Calculate the value of the rate constant, k, for the reaction. Include units with your

Question 2



Question 2

2025 ▪ Q2

Answer the following questions about ascorbic acid (vitamin C).

(b) Ascorbic acid, HAsc(aq), acts as a weak acid, as shown in the equation.

$$\mathrm{HAsc}(aq) + \mathrm{H_2O}(l) \rightleftharpoons \mathrm{H_3O^+}(aq) + \mathrm{Asc^-}(aq)$$

The following titration curve was produced when a 10.0 mL sample of HAsc(aq) was titrated using 0.0550 M NaOH(aq).

[Titration curve graph: x-axis "Volume of 0.0550 M NaOH Added (mL)" from 0.0 to 20.0 in increments of 2.0; y-axis "pH" from 0 to 14 in increments of 2. The curve starts at about (0.0, 2.6), rises gradually and levels into a broad buffer region around pH 4 from about 2 mL to 14 mL, has a small inflection/bump near (14.0, 4.5)-(15.0,

Question 2

5.2), then rises steeply (equivalence point) through the region 15.0-16.5 mL up to about pH 10.5, then levels off gradually approaching about (20.0, 11.3).]

(b)(i) Calculate the molar concentration of the ascorbic acid solution.

(b)(ii) From the titration curve, determine the approximate pK_a of ascorbic acid.

(b)(iii) What is the value of the ratio $\frac{[\text{Asc}^-]}{[\text{HAsc}]}$ when the pH of the solution is 4.7?

Question 2

2025 ▪ Q2

Answer the following questions about ascorbic acid (vitamin C).

(c) Dehydroascorbic acid (DHAsc) can be produced by reacting ascorbic acid with the triiodide ion, I_3^-, as represented by the following equation.

$$HAsc + I_3^- \rightarrow DHAsc + 3\,I^- + 2\,H^+$$

The student runs three trials of the reaction with different initial concentrations of HAsc and I_3^-, producing the following data.

Trial	[HAsc] (M)	[I_3^-] (M)	Initial Rate of DHAsc Formation (M/s)
1	0.450	1.200	2.457×10^{-4}
2	0.450	0.600	1.229×10^{-4}
3	0.900	1.200	4.914×10^{-4}

Question 2

(c)(i) The rate law for the reaction is $rate = k[\text{HAsc}][\text{I}_3^-]$. Explain how the data in the table support the conclusion that the reaction is first order with respect to [HAsc].
(c)(ii) Calculate the value of the rate constant, k, for the reaction. Include units with your answer.

Question 2

2025 ▪ Q2

Answer the following questions about ascorbic acid (vitamin C).

(d) The triiodide ion, I_3^-, is significantly more soluble in water than elemental iodine, I_2, is. Identify an intermolecular force between I_3^- and water that is **not** present between I_2 and water, which could explain the difference in solubility. Lewis diagrams for I_2 and I_3^- are provided.

[Lewis structures: I_2 shown as two iodine atoms singly bonded together, each with three lone pairs. I_3^- shown in brackets with an overall negative charge, as three iodine atoms in a row connected by single bonds (I—I—I), each terminal iodine with three lone pairs and the central iodine with two lone pairs.]

Solution 2

(a)

Mark scheme

- No separate response required — this is the context/stem describing the combustion of ascorbic acid ($C_xH_yO_x$) producing 0.2400 mol CO_2 and 2.883 g H_2O, which parts (i) and (ii) below use.

(a)(i)

Mark scheme

- moles $H_2O = 2.883$ g $H_2O \times \dfrac{1 \text{ mol } H_2O}{18.02 \text{ g } H_2O} = 0.1600$ mol H_2O.

Solution 2

(a)(ii)

Mark scheme

- moles H $= 0.1600$ mol $H_2O \times \dfrac{2 \text{ mol H}}{1 \text{ mol } H_2O} = 0.3200$ mol H (this step may be left implicit). Using mol C $= 0.2400$ mol $CO_2 \times \dfrac{1 \text{ mol C}}{1 \text{ mol } CO_2} = 0.2400$ mol C and the given 1:1 C:O ratio:
  $x : y : z = (\text{mol C}) : (\text{mol H}) : (\text{mol O}) = 0.2400 : 0.3200 : 0.2400 = 3 : 4 : 3.$
  Therefore the empirical formula of ascorbic acid is $C_3H_4O_3$.

Solution 2

(b)

Mark scheme

- No separate response required — this is the context/stem describing HAsc(aq) as a weak acid and presenting the titration curve (10.0 mL HAsc titrated with 0.0550 M NaOH) that parts (i)–(iii) below refer to.

Solution 2

(b)(i)

Mark scheme

- Reading the volume of NaOH at the equivalence point (16.0 mL) from the curve:

$$0.0160 \text{ L NaOH} \times \frac{0.0550 \text{ mol NaOH}}{1 \text{ L NaOH}} \times \frac{1 \text{ mol HAsc}}{1 \text{ mol NaOH}} = 8.80 \times 10^{-4} \text{ mol HAsc.}$$

$$\text{Molarity} = \frac{8.80 \times 10^{-4} \text{ mol HAsc}}{0.0100 \text{ L}} = 0.0880 \ M \text{ HAsc.}$$

Solution 2

(b)(ii)

Mark scheme

- From the titration curve, the pK_a (the pH at the half-equivalence point) is approximately 4.1 (acceptable range 4.0–4.3).

Solution 2

(b)(iii)

Mark scheme

- Using the Henderson–Hasselbalch equation: $\mathrm{pH} = \mathrm{p}K_a + \log\left(\dfrac{[\mathrm{Asc}^-]}{[\mathrm{HAsc}]}\right)$.

  $4.7 = 4.1 + \log\left(\dfrac{[\mathrm{Asc}^-]}{[\mathrm{HAsc}]}\right)$, so $\dfrac{[\mathrm{Asc}^-]}{[\mathrm{HAsc}]} = 10^{0.6} = 4.0$.

Solution 2

(c)

Mark scheme

- No separate response required — this is the context/stem describing the reaction of ascorbic acid (HAsc) with triiodide (I_3^-) to form DHAsc, and the table of three trials' initial concentrations and rates, that parts (i) and (ii) below use.

Solution 2

(c)(i)

Mark scheme

- Comparing trials 1 and 3: $\frac{4.914 \times 10^{-4}}{2.457 \times 10^{-4}} = \left(\frac{0.900}{0.450}\right)^{a}$, thus $a = 1$. The rate doubles when [HAsc] is doubled while $[I_3^-]$ is held constant, indicating the reaction is first order with respect to [HAsc].

Solution 2

(c)(ii)

Mark scheme

- Using rate $= k[\text{HAsc}][\text{I}_3^-]$ and trial 1 data: $k = \dfrac{\text{rate}}{[\text{HAsc}][\text{I}_3^-]} = \dfrac{2.457 \times 10^{-4}\ M/\text{s}}{(0.450\ M)(1.200\ M)} = 4.55 \times 10^{-4}\ M^{-1}\text{s}^{-1}$. Units: $M^{-1}\text{s}^{-1}$.

Solution 2

(d)

Mark scheme

- Ion-dipole attractions are present between I_3^- ions and water but not between I_2 molecules and water. Because I_3^- is a charged ion, it attracts the polar water molecules via ion-dipole forces, giving it much greater solubility than the neutral, nonpolar I_2.

Question 3

2025 ▪ Q3

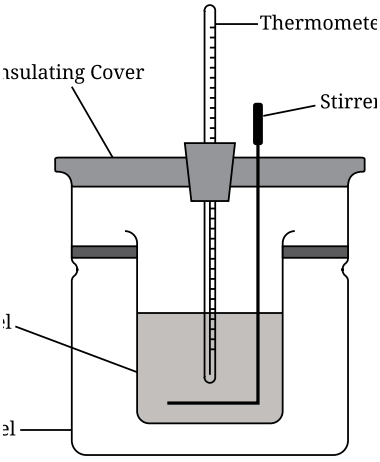
White phosphorus is composed of P_4 molecules with a tetrahedral structure, as shown in the diagram on the left. Each P atom is bonded to the other three P atoms by single bonds, as shown in the incomplete Lewis diagram on the right.

[Left: a ball-and-stick tetrahedral structure of P_4, showing four P atoms (spheres) at the vertices of a tetrahedron connected by bonds (sticks).]

[Right: an incomplete Lewis diagram showing four P atoms arranged in a tetrahedral projection (one P at top, one P in the middle/front, two P at the bottom left and right), connected by single bonds forming the P4 skeleton, with no lone pairs drawn yet.]

(a) In the box in part A, complete the Lewis diagram for P_4 by drawing the nonbonding electrons.

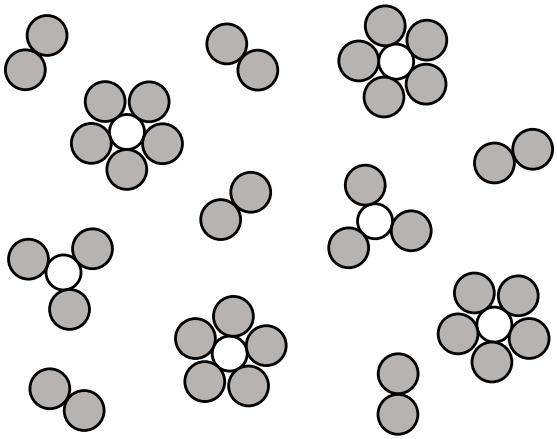
Question 3



Question 3

Mass of P_4O_{10}	0.100 g
Mass of H_2O	100.0 g
Initial temperature	22.00° C
Final temperature	22.38° C
Molar mass of P_4O_{10}	283.9 g/mol
Specific heat of H_2O	4.18 J/$\left(\text{g}\cdot^\circ\text{C}\right)$

Question 3



Question 3

2025 ▪ Q3

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[Right: an incomplete Lewis diagram showing four P atoms arranged in a tetrahedral projection (one P at top, one P in the middle/front, two P at the bottom left and right), connected by single bonds forming the P4 skeleton, with no lone pairs drawn yet.]

(b) The reaction of white phosphorus with oxygen to form $P_4O_{10}(s)$ is thermodynamically favorable at 298 K. The reaction is represented by equation 1.

Equation 1: $P_4(s) + 5\,O_2(g) \rightarrow P_4O_{10}(s)$

Question 3

(b)(i) The entropy change of the reaction, ΔS°, is negative. Using particle-level reasoning, explain why the entropy decreases as the reaction progresses.
(b)(ii) The enthalpy change of the reaction, ΔH°, is also negative. A student claims that the favorability of the reaction is driven by enthalpy and **not** by entropy. Is the student's claim correct? Justify your answer by using the relationship between ΔG°, ΔH°, and ΔS°.

Question 3

2025 ▪ Q3

White phosphorus is composed of P_4 molecules with a tetrahedral structure, as shown in the diagram on the left. Each P atom is bonded to the other three P atoms by single bonds, as shown in the incomplete Lewis diagram on the right.

[Left: a ball-and-stick tetrahedral structure of P_4, showing four P atoms (spheres) at the vertices of a tetrahedron connected by bonds (sticks).]

[Right: an incomplete Lewis diagram showing four P atoms arranged in a tetrahedral projection (one P at top, one P in the middle/front, two P at the bottom left and right), connected by single bonds forming the P4 skeleton, with no lone pairs drawn yet.]

(c) $P_4O_{10}(s)$ reacts exothermically with water to form phosphoric acid, as represented by equation 2.

Equation 2: $P_4O_{10}(s) + 6\,H_2O(l) \rightarrow 4\,H_3PO_4(aq)$

Question 3

A chemist uses a calorimetry experiment to determine the enthalpy change for the reaction, as represented by the following diagram.

[Calorimeter diagram: a coffee-cup-style calorimeter labeled "Thermometer" (inserted through the insulating cover), "Stirrer" (inserted alongside the thermometer), "Insulating Cover" (the lid), "Inner Vessel" (the cup holding the solution, shaded), and "Outer Vessel" (the outer supporting cup).]

The chemist carries out the calorimetry experiment and records the following information.

Quantity	Value
Mass of P_4O_{10}	0.100 g
Mass of H_2O	100.0 g
Initial temperature	22.00°C
Final temperature	22.38°C
Molar mass of P_4O_{10}	283.9 g/mol
Specific heat of H_2O	4.18 J/(g $\cdot^\circ$ C)

(c)(i) Calculate the amount of heat, q, released during the experiment, in kJ. Assume that the specific heat of the solution is the same as that of water.

Question 3

(c)(ii) Calculate the value of ΔH°_{rxn} for equation 2 in kJ/mol_{rxn}. Include the sign in your answer.

Question 3

2025 ▪ Q3

White phosphorus is composed of P_4 molecules with a tetrahedral structure, as shown in the diagram on the left. Each P atom is bonded to the other three P atoms by single bonds, as shown in the incomplete Lewis diagram on the right.

[Left: a ball-and-stick tetrahedral structure of P_4, showing four P atoms (spheres) at the vertices of a tetrahedron connected by bonds (sticks).]

[Right: an incomplete Lewis diagram showing four P atoms arranged in a tetrahedral projection (one P at top, one P in the middle/front, two P at the bottom left and right), connected by single bonds forming the P4 skeleton, with no lone pairs drawn yet.]

(d) The chemist weighed out 0.100 g P_4O_{10} of and 100.0 g of H_2O to perform a second trial. In the second trial, some of the solid P_4O_{10} stuck to the weighing paper and was not transferred to the calorimeter. Given that P_4O_{10} is the limiting reactant,

Question 3

would ΔT for the second trial be greater than, less than, or equal to the value in the first trial? Justify your answer.

$P_4(s)$ also reacts readily with $Cl_2(g)$ to produce phosphorus trichloride, $PCl_3(g)$, which in turn reacts with $Cl_2(g)$ in an equilibrium process to produce $PCl_5(g)$. The reactions are represented by equations 3 and 4.

Equation 3: $P_4(s) + 6\,Cl_2(g) \rightarrow 4\,PCl_3(g) \qquad \Delta H_1^\circ = -1148\ \text{kJ/mol}_{rxn}$

Equation 4: $PCl_3(g) + Cl_2(g) \rightleftharpoons PCl_5(g) \qquad \Delta H_2^\circ = -88\ \text{kJ/mol}_{rxn}$

Question 3

2025 ▪ Q3

White phosphorus is composed of P_4 molecules with a tetrahedral structure, as shown in the diagram on the left. Each P atom is bonded to the other three P atoms by single bonds, as shown in the incomplete Lewis diagram on the right.

[Left: a ball-and-stick tetrahedral structure of P_4, showing four P atoms (spheres) at the vertices of a tetrahedron connected by bonds (sticks).]

[Right: an incomplete Lewis diagram showing four P atoms arranged in a tetrahedral projection (one P at top, one P in the middle/front, two P at the bottom left and right), connected by single bonds forming the P4 skeleton, with no lone pairs drawn yet.]

(e) Calculate the standard enthalpy of formation of $PCl_5(g)$ represented by equation 5.

Equation 5: $\frac{1}{4}P_4(s) + \frac{5}{2}Cl_2(g) \rightarrow PCl_5(g) \qquad \Delta H_f^\circ = ?$

The following particle-level diagram represents the contents of the vessel in an equilibrium mixture at 546 K involving equation 4.

Question 3

[Particle diagram: a box containing multiple particles at random positions representing an equilibrium mixture; a key indicates two-atom particles (grey-grey) = Cl_2, four-atom tetrahedral-looking particles (grey with three white) = PCl_3, and six-atom particles (grey with five white) = PCl_5. The box shows several Cl_2 particles (pairs of grey circles), several PCl_3 particles (grey center with three white circles), and several PCl_5 particles (grey center with five white circles) scattered throughout.]

Question 3

2025 ▪ Q3

White phosphorus is composed of P_4 molecules with a tetrahedral structure, as shown in the diagram on the left. Each P atom is bonded to the other three P atoms by single bonds, as shown in the incomplete Lewis diagram on the right.

[Left: a ball-and-stick tetrahedral structure of P_4, showing four P atoms (spheres) at the vertices of a tetrahedron connected by bonds (sticks).]

[Right: an incomplete Lewis diagram showing four P atoms arranged in a tetrahedral projection (one P at top, one P in the middle/front, two P at the bottom left and right), connected by single bonds forming the P4 skeleton, with no lone pairs drawn yet.]

(f) Equation 4 for the reaction that occurs is shown.

Equation 4: $PCl_3(g) + Cl_2(g) \rightleftharpoons PCl_5(g) \qquad \Delta H^\circ_2 = -88 \text{ kJ/mol}_{rxn}$

(f)(i) If each particle in the diagram represents a partial pressure of 1.00 atm, what is the value of K_p for the equilibrium mixture at 546 K?

Question 3

(f)(ii) Does the value of K_p increase, decrease, or remain the same when the temperature is increased to 596 K? Justify your answer based on ΔH°_{2}.

Solution 3

(a)

Mark scheme

- Complete Lewis diagram for P_4: the four P atoms form a tetrahedron, each bonded to the other three P atoms by single bonds, and each P atom bears one lone (nonbonding) pair of electrons — giving each P three bonding pairs plus one lone pair, satisfying the octet rule.

Solution 3

(b)

Mark scheme

- No separate response required — this is the context/stem presenting equation 1 ($P_4(s) + 5\,O_2(g) \rightarrow P_4O_{10}(s)$), thermodynamically favorable at 298 K, that parts (i) and (ii) below refer to.

(b)(i)

Mark scheme

- Because gas particles are more dispersed (have more accessible microstates) than solids, the entropy decreases as the reactants (which include a gas, O_2) convert into the solid product (P_4O_{10}).

Solution 3

(b)(ii)

Mark scheme

- Yes, the student's claim is correct. Given $\Delta G^\circ_{rxn} = \Delta H^\circ_{rxn} - T\Delta S^\circ_{rxn}$, the reaction must have $\Delta G^\circ_{rxn} < 0$ to be favorable. Because the reaction is exothermic, $\Delta H^\circ_{rxn} < 0$ and enthalpy contributes to favorability. $\Delta S^\circ_{rxn} < 0$, so entropy does NOT contribute to favorability — i.e., enthalpy alone drives it.

Solution 3

(c)

Mark scheme

- No separate response required — this is the context/stem describing the calorimetry experiment for the exothermic reaction of $P_4O_{10}(s)$ with water (equation 2: $P_4O_{10}(s) + 6\,H_2O(l) \rightarrow 4\,H_3PO_4(aq)$) that parts (i) and (ii) below use.

Solution 3

(c)(i)

Mark scheme

- $q = mc\Delta T = (100.1\ \text{g})(4.18\ \text{J/(g}\cdot^\circ\text{C)})(22.38^\circ\text{C} - 22.00^\circ\text{C}) = 160\ \text{J} = 0.16\ \text{kJ}$ (reported to the correct number of significant figures).

Solution 3

(c)(ii)

Mark scheme

- $q_{rxn} = -q_{surr} = -0.16$ kJ.
  $\Delta H^{\circ}_{rxn} = \dfrac{-0.16 \text{ kJ}}{0.100 \text{ g } P_4O_{10}} \times \dfrac{283.9 \text{ g } P_4O_{10}}{1 \text{ mol } P_4O_{10}} \times \dfrac{1 \text{ mol } P_4O_{10}}{1 \text{ mol}_{rxn}} = -450 \text{ kJ/mol}_{rxn}.$
  The correct (negative) sign must be included.

Solution 3

(d)

Mark scheme

- Less than. If less P_4O_{10} is present (some stuck to the weighing paper), less thermal energy will be transferred to the water during the reaction, causing the temperature increase (ΔT) to be less than it was with the full 0.100 g of P_4O_{10}.

Solution 3

(e)

Mark scheme

- Using Hess's law:

$$\Delta H^{\circ}_{f,\mathrm{PCl_5}(g)} = \frac{1}{4}\Delta H^{\circ}_1 + \Delta H^{\circ}_2 = \frac{1}{4}(-1148) + (-88) = -375 \text{ kJ/mol}.$$

Solution 3

(f)

Mark scheme

- No separate response required — this is the context/stem presenting equation 4 ($PCl_3(g) + Cl_2(g) \rightleftharpoons PCl_5(g)$, $\Delta H_2^\circ = -88$ kJ/mol$_{rxn}$) that parts (i) and (ii) below refer to.

Solution 3

(f)(i)

Mark scheme

- Reading partial pressures of 1.00 atm per particle from the diagram (4 PCl_5, 2 PCl_3, 6 Cl_2 particles): $K_p = \dfrac{P_{PCl_5}}{(P_{PCl_3})(P_{Cl_2})} = \dfrac{4.00}{(2.00)(6.00)} = \dfrac{1}{3} = 0.333.$

Solution 3

(f)(ii)

Mark scheme

- Decrease. The negative value of ΔH_2° indicates the reaction is exothermic. Because exothermic reactions favor reactant formation at higher temperature (the equilibrium shifts toward reactants as heat is added), the value of K_p decreases.

Question 6

2025 ▪ Q6

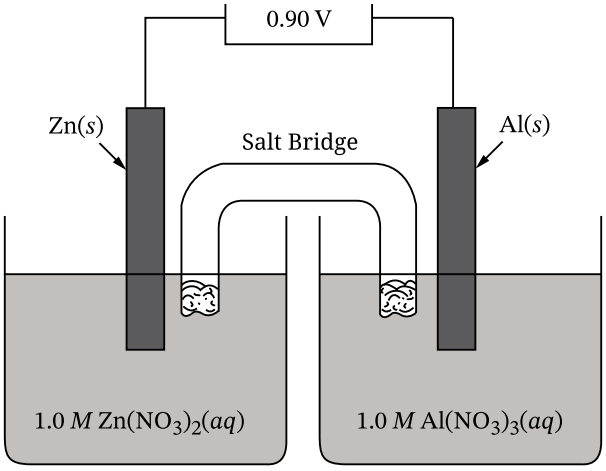
A scientist constructs a galvanic cell as shown in the diagram. As the cell operates, the $\mathrm{Zn}(s)$ electrode increases in mass and the $\mathrm{Al}(s)$ electrode decreases in mass. A data table with the standard reduction potentials for the substances follows the diagram.

[Galvanic cell diagram: a voltmeter reading "0.90 V" connects two electrodes across the top. The left electrode is labeled "$\mathrm{Zn}(s)$" (with an arrow pointing to it), immersed in a beaker of "$1.0\ M\ \mathrm{Zn(NO_3)_2}(aq)$". The right electrode is labeled "$\mathrm{Al}(s)$" (with an arrow pointing to it), immersed in a beaker of "$1.0\ M\ \mathrm{Al(NO_3)_3}(aq)$". The two beakers are connected by a U-shaped "Salt Bridge" with cotton plugs at each end, shown dipping into each solution.]

| Half-Reaction | E° (V) | |—|—| | $\mathrm{Zn}^{2+}(aq) + 2\,e^- \rightarrow \mathrm{Zn}(s)$ | -0.76 | | $\mathrm{Al}^{3+}(aq) + 3\,e^- \rightarrow \mathrm{Al}(s)$ | -1.66 |

(a) Write the half-reaction for the oxidation that occurs at the anode.

Question 6



Question 6

Reduction Half-Reaction	$E^\circ\ (\mathrm{V})$
$\mathrm{Au}^{3+}(aq) + 3\ e^- \rightarrow \mathrm{Au}(s)$	$+1.50$
$\mathrm{Zn}^{2+}(aq) + 2\ e^- \rightarrow \mathrm{Zn}(s)$	-0.76
$\mathrm{Mn}^{2+}(aq) + 2\ e^- \rightarrow \mathrm{Mn}(s)$	-1.19
$\mathrm{Al}^{3+}(aq) + 3\ e^- \rightarrow \mathrm{Al}(s)$	-1.66
$\mathrm{Be}^{2+}(aq) + 2\ e^- \rightarrow \mathrm{Be}(s)$	-1.85

Question 6

Half-Reaction	$E^\circ\ (\mathrm{V})$
$\mathrm{Zn}^{2+}(aq) + 2\ e^- \rightarrow \mathrm{Zn}(s)$	-0.76
$\mathrm{Al}^{3+}(aq) + 3\ e^- \rightarrow \mathrm{Al}(s)$	-1.66

Question 6

2025 ▪ Q6

A scientist constructs a galvanic cell as shown in the diagram. As the cell operates, the Zn(s) electrode increases in mass and the Al(s) electrode decreases in mass. A data table with the standard reduction potentials for the substances follows the diagram.

[Galvanic cell diagram: a voltmeter reading "0.90 V" connects two electrodes across the top. The left electrode is labeled "Zn(s)" (with an arrow pointing to it), immersed in a beaker of "1.0 M $Zn(NO_3)_2(aq)$". The right electrode is labeled "Al(s)" (with an arrow pointing to it), immersed in a beaker of "1.0 M $Al(NO_3)_3(aq)$". The two beakers are connected by a U-shaped "Salt Bridge" with cotton plugs at each end, shown dipping into each solution.]

| Half-Reaction | E° (V) | |—|—| | $Zn^{2+}(aq) + 2\,e^- \rightarrow Zn(s)$ | -0.76 | | $Al^{3+}(aq) + 3\,e^- \rightarrow Al(s)$ | -1.66 |

(b) Write the balanced net ionic equation for the overall reaction that occurs in the galvanic cell.

Question 6

2025 ▪ Q6

A scientist constructs a galvanic cell as shown in the diagram. As the cell operates, the Zn(s) electrode increases in mass and the Al(s) electrode decreases in mass. A data table with the standard reduction potentials for the substances follows the diagram.

[Galvanic cell diagram: a voltmeter reading "0.90 V" connects two electrodes across the top. The left electrode is labeled "Zn(s)" (with an arrow pointing to it), immersed in a beaker of "1.0 M $Zn(NO_3)_2(aq)$". The right electrode is labeled "Al(s)" (with an arrow pointing to it), immersed in a beaker of "1.0 M $Al(NO_3)_3(aq)$". The two beakers are connected by a U-shaped "Salt Bridge" with cotton plugs at each end, shown dipping into each solution.]

| Half-Reaction | E° (V) | |—|—| | $Zn^{2+}(aq) + 2\,e^- \rightarrow Zn(s)$ | -0.76 | | $Al^{3+}(aq) + 3\,e^- \rightarrow Al(s)$ | -1.66 |

(c) Initially, each electrode has a mass of 50.0 g. The cell is allowed to run for a period of time and is then stopped. Which electrode's mass changed the most? Justify your answer with a calculation.

Question 6

| Reduction Half-Reaction | E° (V) | |—|—| | $Au^{3+}(aq) + 3\,e^- \rightarrow Au(s)$ | $+1.50$ | | $Zn^{2+}(aq) + 2\,e^- \rightarrow Zn(s)$ | -0.76 | | $Mn^{2+}(aq) + 2\,e^- \rightarrow Mn(s)$ | -1.19 | | $Al^{3+}(aq) + 3\,e^- \rightarrow Al(s)$ | -1.66 | | $Be^{2+}(aq) + 2\,e^- \rightarrow Be(s)$ | -1.85 |

Question 6

2025 ▪ Q6

A scientist constructs a galvanic cell as shown in the diagram. As the cell operates, the Zn(s) electrode increases in mass and the Al(s) electrode decreases in mass. A data table with the standard reduction potentials for the substances follows the diagram.

[Galvanic cell diagram: a voltmeter reading "0.90 V" connects two electrodes across the top. The left electrode is labeled "Zn(s)" (with an arrow pointing to it), immersed in a beaker of "1.0 M $Zn(NO_3)_2(aq)$". The right electrode is labeled "Al(s)" (with an arrow pointing to it), immersed in a beaker of "1.0 M $Al(NO_3)_3(aq)$". The two beakers are connected by a U-shaped "Salt Bridge" with cotton plugs at each end, shown dipping into each solution.]

| Half-Reaction | E° (V) | |—|—| | $Zn^{2+}(aq) + 2\,e^- \rightarrow Zn(s)$ | -0.76 | | $Al^{3+}(aq) + 3\,e^- \rightarrow Al(s)$ | -1.66 |

(d) The standard Zn/Al cell has a value of E°_{cell} equal to 0.90 V. The scientist needs a galvanic cell that produces a greater voltage. The scientist has access to the chemical systems in the table. If the scientist uses the Zn half-cell and one of the other options

Question 6

from the table, what is the MAXIMUM voltage that could be generated at standard conditions?

Solution 6

(a)

Mark scheme

- $\mathrm{Al}(s) \rightarrow \mathrm{Al}^{3+}(aq) + 3\,e^{-}$ (oxidation half-reaction at the anode; state symbols not required).

Solution 6

(b)

Mark scheme

- $2\,\mathrm{Al}(s) + 3\,\mathrm{Zn}^{2+}(aq) \rightarrow 2\,\mathrm{Al}^{3+}(aq) + 3\,\mathrm{Zn}(s)$ (balanced net ionic equation for the overall galvanic cell reaction; state symbols not required).

Solution 6

(c) Mark scheme

- Zn experiences the greater change in mass. Assuming the entire 50.0 g Al anode reacts: 50.0 g Al $\times \dfrac{1 \text{ mol Al}}{26.98 \text{ g Al}} \times \dfrac{3 \text{ mol Zn}}{2 \text{ mol Al}} \times \dfrac{65.38 \text{ g Zn}}{1 \text{ mol Zn}} = 182$ g Zn produced — far more than the 50.0 g of Al consumed. Equivalently, per mole of reaction: 3 mol Zn $\times$ 65.38 g/mol $=$ 196.1 g Zn deposited vs. 2 mol Al $\times$ 26.98 g/mol $=$ 53.96 g Al consumed, so the mass of Zn produced always exceeds the mass of Al consumed.

Solution 6

(d)

Mark scheme

- Pair the Zn half-cell (oxidation: $\mathrm{Zn}(s) \rightarrow \mathrm{Zn}^{2+}(aq) + 2\,e^-$, $E^\circ = +0.76$ V) with the $\mathrm{Au}^{3+}/\mathrm{Au}$ half-reaction as the cathode ($E^\circ = +1.50$ V, the largest reduction potential available, greater than Mn or Al): $E^\circ_{cell} = 1.50\ \mathrm{V} + 0.76\ \mathrm{V} = 2.26\ \mathrm{V}$. This is the maximum voltage obtainable from the table.

Question 2

2024 ▪ Q2

$$H_2C_4H_2O_4(aq) + 2\,NaHCO_3(aq) \rightarrow 2\,CO_2(g) + 2\,H_2O(l) + Na_2C_4H_2O_4(aq)$$

2. A chemical reaction between maleic acid ($H_2C_4H_2O_4$) and sodium bicarbonate ($NaHCO_3$) occurs in the presence of water to produce carbon dioxide and sodium maleate ($Na_2C_4H_2O_4$), as represented by the following equation.

(a)(i) A student combines equal masses of $H_2C_4H_2O_4(s)$ chunks and $NaHCO_3(s)$ chunks with sufficient water at 20.0°C. The student determines that 0.0114 mol of $CO_2(g)$ is produced after the reaction goes to completion.

Calculate the number of grams of $CO_2(g)$ produced.

(a)(ii) The $CO_2(g)$ produced from the reaction at 20.0°C was collected and found to have a pressure of 1.25 atm. Calculate the volume of $CO_2(g)$, in liters.

Question 2

2024 ▪ Q2

$$H_2C_4H_2O_4(aq) + 2\,NaHCO_3(aq) \rightarrow 2\,CO_2(g) + 2\,H_2O(l) + Na_2C_4H_2O_4(aq)$$

2. A chemical reaction between maleic acid ($H_2C_4H_2O_4$) and sodium bicarbonate ($NaHCO_3$) occurs in the presence of water to produce carbon dioxide and sodium maleate ($Na_2C_4H_2O_4$), as represented by the following equation.

(b)(i) The student performs a second experiment that is identical to the first except that the student grinds the chunks of $H_2C_4H_2O_4(s)$ and $NaHCO_3(s)$ into powder before combining the powder with water.

What happens to the surface area of the reactants when the student grinds the chunks into powder?

Question 2

(b)(ii) The rate-determining step for the overall reaction is the dissolving of the solids. Would the time required for the dissolving of the solids in the second experiment be longer than, shorter than, or the same as the time required in the first experiment? Justify your answer based on the collisions between particles.

(b)(iii) When the reaction is complete, will the volume of $CO_2(g)$ at the end of the second experiment be greater than, less than, or equal to the volume at the end of the first experiment? Justify your answer.

Question 2

2024 ▪ Q2

$$H_2C_4H_2O_4(aq) + 2\,NaHCO_3(aq) \rightarrow 2\,CO_2(g) + 2\,H_2O(l) + Na_2C_4H_2O_4(aq)$$

2. A chemical reaction between maleic acid ($H_2C_4H_2O_4$) and sodium bicarbonate ($NaHCO_3$) occurs in the presence of water to produce carbon dioxide and sodium maleate ($Na_2C_4H_2O_4$), as represented by the following equation.

(c) The student conducts additional trials of the experiment and produces the following data table.

Trial	Mass of $H_2C_4H_2O_4$ (grams)	Mass of $NaHCO_3$ (grams)	Moles of CO_2 Produced (mol)
3	1.543	1.251	0.01489
4	1.543	1.686	0.02007

Based on the student's data, identify the limiting reactant in trial 3. Justify your answer.

Question 2

2024 ▪ Q2

$$H_2C_4H_2O_4(aq) + 2\,NaHCO_3(aq) \rightarrow 2\,CO_2(g) + 2\,H_2O(l) + Na_2C_4H_2O_4(aq)$$

2. A chemical reaction between maleic acid ($H_2C_4H_2O_4$) and sodium bicarbonate ($NaHCO_3$) occurs in the presence of water to produce carbon dioxide and sodium maleate ($Na_2C_4H_2O_4$), as represented by the following equation.

(d) The reaction has a value of ΔS° greater than zero. Using particle-level reasoning, explain why the entropy increases as the reaction progresses.

Question 2

2024 ▪ Q2

$$H_2C_4H_2O_4(aq) + 2\,NaHCO_3(aq) \rightarrow 2\,CO_2(g) + 2\,H_2O(l) + Na_2C_4H_2O_4(aq)$$

2. A chemical reaction between maleic acid ($H_2C_4H_2O_4$) and sodium bicarbonate ($NaHCO_3$) occurs in the presence of water to produce carbon dioxide and sodium maleate ($Na_2C_4H_2O_4$), as represented by the following equation.

(e) The student notices that the temperature of the reaction mixture decreases as the reaction takes place and correctly determines that the reaction is endothermic.
The student claims that the reaction is thermodynamically favorable at all temperatures because $\Delta S^\circ_{rxn} > 0$ and the reaction is endothermic. Do you agree or disagree with the student's claim? Justify your answer.

Question 2

2024 ▪ Q2

$$H_2C_4H_2O_4(aq) + 2\,NaHCO_3(aq) \rightarrow 2\,CO_2(g) + 2\,H_2O(l) + Na_2C_4H_2O_4(aq)$$

2. A chemical reaction between maleic acid ($H_2C_4H_2O_4$) and sodium bicarbonate ($NaHCO_3$) occurs in the presence of water to produce carbon dioxide and sodium maleate ($Na_2C_4H_2O_4$), as represented by the following equation.

(f) Next, the student investigates the acid-base behavior of maleic acid. The student notes that maleic acid is a diprotic acid. The two acid dissociation processes that occur are represented by the following equations.

$$H_2C_4H_2O_4 + H_2O \rightleftharpoons HC_4H_2O_4^- + H_3O^+ \qquad K_{a_1} = 1.5 \times 10^{-2}$$

$$HC_4H_2O_4^- + H_2O \rightleftharpoons C_4H_2O_4^{2-} + H_3O^+ \qquad K_{a_2} = 8.5 \times 10^{-7}$$

Question 2

Calculate the pK_{a_2} value for the $HC_4H_2O_4^-$ ion.

Question 2

2024 ▪ Q2

$$H_2C_4H_2O_4(aq) + 2\,NaHCO_3(aq) \rightarrow 2\,CO_2(g) + 2\,H_2O(l) + Na_2C_4H_2O_4(aq)$$

2. A chemical reaction between maleic acid ($H_2C_4H_2O_4$) and sodium bicarbonate ($NaHCO_3$) occurs in the presence of water to produce carbon dioxide and sodium maleate ($Na_2C_4H_2O_4$), as represented by the following equation.

(g) A buffer solution with a pH of 7.00 is prepared using $C_4H_2O_4^{2-}$ and $HC_4H_2O_4^-$. Calculate the ratio

$$\frac{[C_4H_2O_4^{2-}]}{[HC_4H_2O_4^-]}$$

in this solution.

Solution 2

(a)(i)

Mark scheme

- 0.0114 mol $CO_2 \times \dfrac{44.01\ \text{g}}{1\ \text{mol}} = 0.502\ \text{g}\ CO_2$.

Solution 2

(a)(ii)

Mark scheme

- Using $PV = nRT$:
  $$V = \frac{nRT}{P} = \frac{(0.0114\ \text{mol})(0.08206\ \text{L} \cdot \text{atm}/(\text{mol} \cdot \text{K}))(293\ \text{K})}{1.25\ \text{atm}} = 0.219\ \text{L}.$$

Solution 2

(b)(i)

Mark scheme

- Claim: the surface area of the solid reactants increases when the chunks are ground into powder.

(b)(ii)

Mark scheme

- Shorter than. The powdered solids have a larger surface area than the solid chunks, so collisions between water molecules and the solid surface particles occur more frequently, resulting in a faster rate of dissolution and a shorter time to dissolve the solids.

Solution 2

(b)(iii)

Mark scheme

- Equal to. Both experiments begin with the same amount (mass) of reactants, so they produce the same number of moles of $CO_2(g)$ under the same conditions of pressure and temperature; therefore the final volume of CO_2 will be the same regardless of particle size (rate changes, but the final amount/volume does not).

Solution 2

(c) Mark scheme

- $NaHCO_3$ is the limiting reactant (accept either justification): changing the mass of $NaHCO_3$ alters the amount of CO_2 produced, OR $NaHCO_3$ has the smaller theoretical yield of CO_2:
  1.543 g $H_2C_4H_2O_4 \times \dfrac{1 \text{ mol}}{116.07 \text{ g}} \times \dfrac{2 \text{ mol } CO_2}{1 \text{ mol acid}} = 0.02659$ mol CO_2 (if acid were limiting) vs. 1.251 g $NaHCO_3 \times \dfrac{1 \text{ mol}}{84.01 \text{ g}} \times \dfrac{2 \text{ mol } CO_2}{2 \text{ mol } NaHCO_3} = 0.01489$ mol CO_2 (if $NaHCO_3$ limiting) — the smaller value ($NaHCO_3$) is the actual limiting reactant, matching the trial's observed 0.01489 mol CO_2.

Solution 2

(d)

Mark scheme

- The entropy change is positive because the aqueous/solid reactants produce 2 moles of gas (CO_2) particles, according to the balanced equation. Gases are far more dispersed (occupy many more microstates) than condensed (solid/aqueous) phases, so the entropy of the products is greater than that of the reactants.

Solution 2

(e)

Mark scheme

- Disagree. Accept either justification: (1) The reaction is endothermic ($\Delta H > 0$) with a positive entropy change ($\Delta S > 0$), so it is only thermodynamically favorable at a high enough temperature where the magnitude of $-T\Delta S$ exceeds ΔH — NOT at all temperatures. (2) For a reaction to be thermodynamically favorable ($\Delta G < 0$) at ALL temperatures, it must be exothermic ($\Delta H < 0$) AND have $\Delta S > 0$ — this reaction is endothermic, so it fails that requirement.

Solution 2

(f)

Mark scheme

- Given $K_{a_2} = 8.5 \times 10^{-7}$ for the second dissociation of maleic acid: $\mathrm{p}K_{a_2} = -\log(8.5 \times 10^{-7}) = 6.07$.

Solution 2

(g)

Mark scheme

- Using the Henderson–Hasselbalch equation: $\mathrm{pH} = \mathrm{p}K_{a_2} + \log \dfrac{[\mathrm{C_4H_2O_4^{2-}}]}{[\mathrm{HC_4H_2O_4^-}]}$.

  Solving: $\dfrac{[\mathrm{C_4H_2O_4^{2-}}]}{[\mathrm{HC_4H_2O_4^-}]} = 10^{(\mathrm{pH}-\mathrm{p}K_{a_2})} = 10^{(7.00-6.07)} = 8.5.$

Question 3

2024 ▪ Q3

$$2\,\mathrm{Ag}(s) + \mathrm{H_2S}(g) \rightarrow \mathrm{Ag_2S}(s) + \mathrm{H_2}(g)$$

3. Sterling silver is an alloy that is commonly used to make jewelry and consists of 92.5

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

$\mathrm{Ag}(s)$ $\mathrm{Ag_2S}(s)$