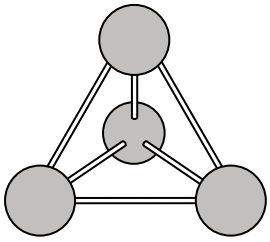
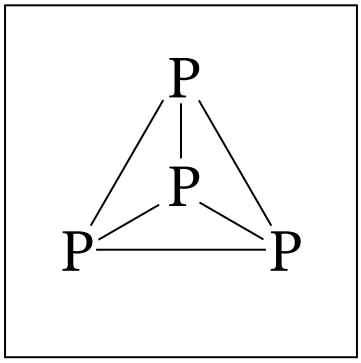
3. White phosphorus is composed of P_4 molecules with a tetrahedral structure, as shown in the diagram on the left. Each P atom is bonded to the other three P atoms by single bonds, as shown in the incomplete Lewis diagram on the right.





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

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

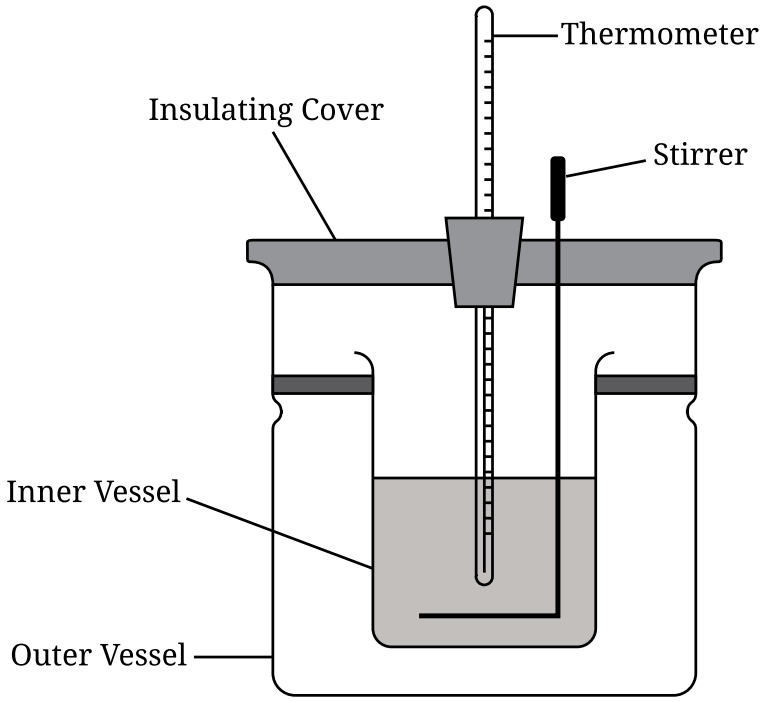
i. The entropy change of the reaction, ΔS°, is negative. Using particle-level reasoning, explain why the entropy decreases as the reaction progresses.

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°.

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

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

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



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

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 $J/(g\cdot°C)$

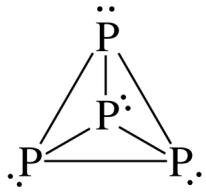
i. Calculate the amount of heat, *q*, released during the experiment, in kJ. Assume that the specific heat of the solution is the same as that of water.

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

Question 3: Long Answer — 10 points

A — **Point 01**

For the correct diagram:



B — **Point 02**

(i) For a correct explanation:

Because gas particles are more dispersed (have more microstates) than solids, the entropy decreases as the reactants (which include a gas) convert to the solid product.

Point 03

(ii) For the correct answer and a valid justification:

Yes. Given that $\Delta G^\circ_{rxn} = \Delta H^\circ_{rxn} - T\Delta S^\circ_{rxn}$*, 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.*

C — **Point 04**

(i) For the correct calculated value reported with the correct number of significant figures:

$q = mc\Delta T = (100.1\text{ g})(4.18\text{ J/(g}\cdot\text{°C)})(22.38\text{°C} - 22.00\text{°C})$

$q = 160\text{ J} = 0.16\text{ kJ}$

Point 05

(ii) For the correct calculated value, consistent with part C (i):

$q_{rxn} = -q_{surr} = -0.16\text{ kJ}$

$$\Delta H^\circ_{rxn} = \frac{-0.16\text{ kJ}}{0.100\text{ g } P_4O_{10}} \times \frac{283.9\text{ g } P_4O_{10}}{1\text{ mol } P_4O_{10}} \times \frac{1\text{ mol } P_4O_{10}}{1\text{ mol}_{rxn}} = -450\text{ kJ/mol}_{rxn}$$

Point 06

For the correct sign:

-450 kJ/mol_{rxn}

D — **Point 07**

For the correct answer and a valid justification:

Less than. If less P_4O_{10} *is present, less thermal energy will be transferred to the water during the reaction, causing the temperature increase to be less than it was with* 0.100 g *of* P_4O_{10}.