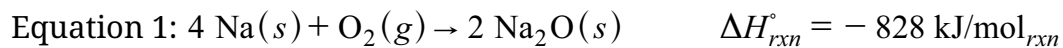


Question 7

The following information applies to parts A and B.

7. Sodium metal reacts with oxygen gas according to Equation 1.



Standard enthalpies of formation are provided in Table 1.

Table 1

Substance	ΔH_f° (kJ/mol)
Na(s)	0
O ₂ (g)	0
Na ₂ O(s)	?

Part A

Based on the information given, **calculate** the value of ΔH_f° for Na₂O(s). Show the work that leads to your answer.

Part B

An 18.4 g sample of Na(s) reacts with 12.8 g of O₂(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.

Part C

Lattice enthalpy can be defined as the energy required to separate an ionic crystal into gaseous ions. $\text{Rb}_2\text{O}(s)$ and $\text{Na}_2\text{O}(s)$ have similar crystal structures, and their lattice enthalpies are given in Table 2.

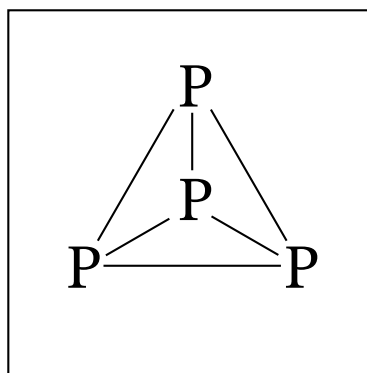
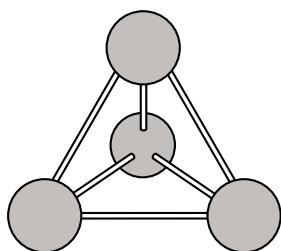
Table 2

Compound	Lattice Enthalpy (kJ/mol)
$\text{Na}_2\text{O}(s)$	2481
$\text{Rb}_2\text{O}(s)$	2163

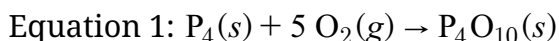
Using Coulomb's law, **explain** why the lattice enthalpy of $\text{Rb}_2\text{O}(s)$ is smaller than that of $\text{Na}_2\text{O}(s)$.

STOP
END OF EXAM

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.

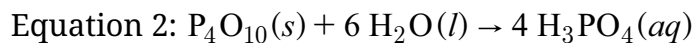


- A. In the box in part A, complete the Lewis diagram for P_4 by drawing the nonbonding electrons.
- B. The reaction of white phosphorus with oxygen to form $P_4O_{10}(s)$ is thermodynamically favorable at 298 K. The reaction is represented by equation 1.

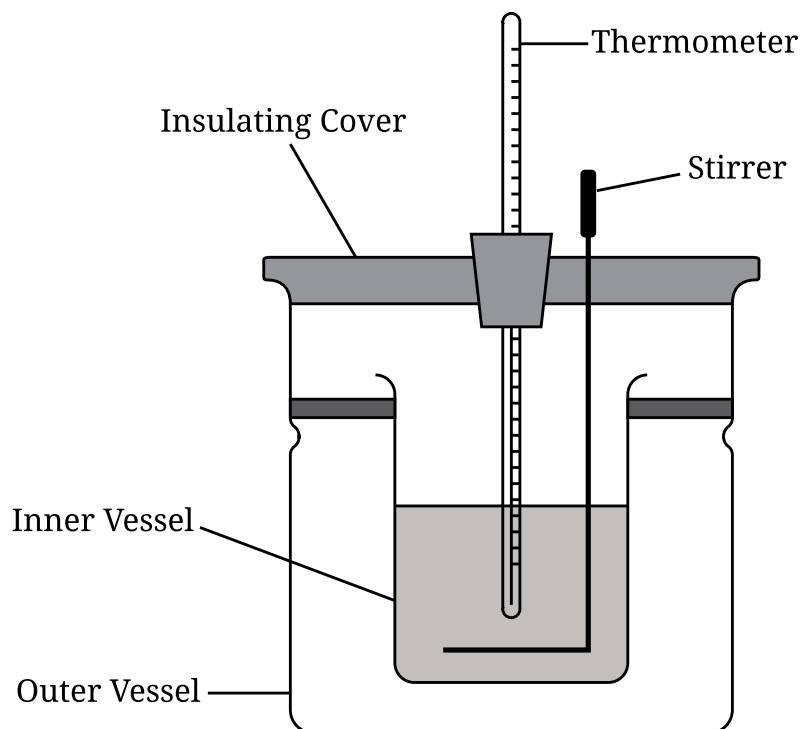


- The entropy change of the reaction, ΔS° , is negative. Using particle-level reasoning, explain why the entropy decreases as the reaction progresses.
- The enthalpy change of the reaction, ΔH° , is also negative. A student claims that the favorability of the reaction is driven by enthalpy and **not**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

$\text{P}_4\text{O}_{10}(s)$ reacts exothermically with water to form phosphoric acid, as represented by equation 2.



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



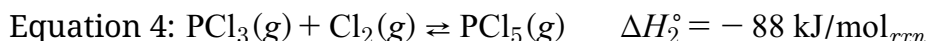
C. The chemist carries out the calorimetry experiment and records the following information.

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·°C)

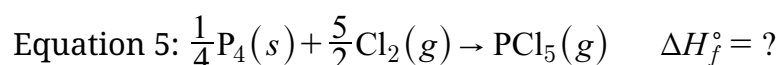
- Calculate the amount of heat, q , released during the experiment, in kJ. Assume that the specific heat of the solution is the same as that of water.
- Calculate the value of $\Delta H^\circ_{\text{rxn}}$ for equation 2 in kJ/mol_{rxn}. Include the sign in your answer.

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

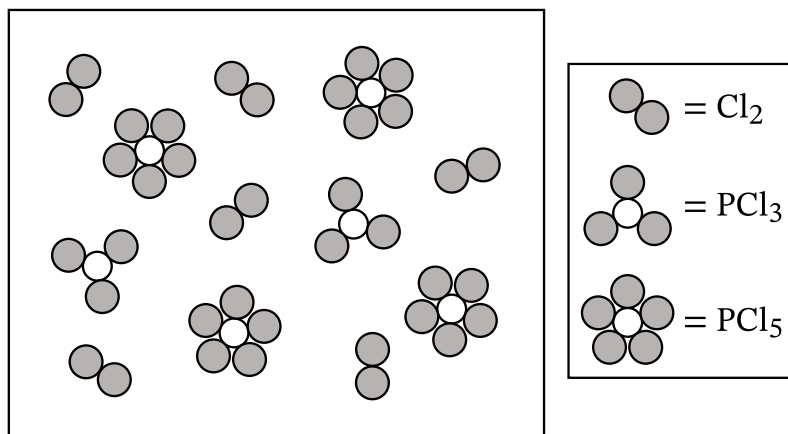
$\text{P}_4(s)$ also reacts readily with $\text{Cl}_2(g)$ to produce phosphorus trichloride, $\text{PCl}_3(g)$, which in turn reacts with $\text{Cl}_2(g)$ in an equilibrium process to produce $\text{PCl}_5(g)$. The reactions are represented by equations 3 and 4.



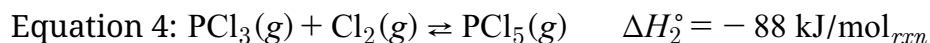
- E. Calculate the standard enthalpy of formation of $\text{PCl}_5(g)$ represented by equation 5.



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

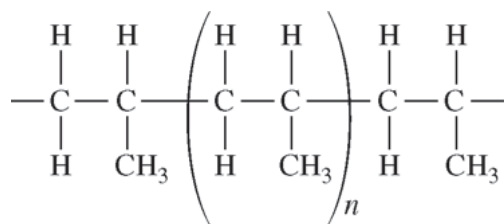


- F. Equation 4 for the reaction that occurs is shown.

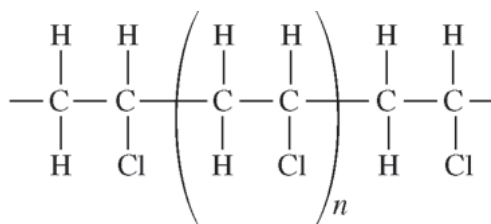


- If each particle in the diagram represents a partial pressure of 1.00 atm, what is the value of K_p for the equilibrium mixture at 546 K?
- Does the value of K_p increase, decrease, or remain the same when the temperature is increased to 596 K? Justify your answer based on ΔH_2° .

6. A student places a mixture of plastic beads consisting of polypropylene (PP) and polyvinyl chloride (PVC) in a 1.0 L beaker containing distilled water. After stirring the contents of the beaker vigorously, the student observes that the beads of one type of plastic sink to the bottom of the beaker and the beads of the other type of plastic float on the water. The chemical structures of PP and PVC are represented by the diagrams below, which show segments of each polymer.



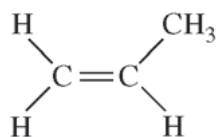
PP



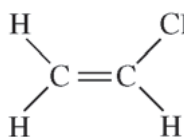
PVC

- (a) Given that the spacing between polymer chains in PP and PVC is similar, the beads that sink are made of which polymer? Explain.

PP is synthesized from propene, C_3H_6 , and PVC is synthesized from vinyl chloride, $\text{C}_2\text{H}_3\text{Cl}$. The structures of the molecules are shown below.



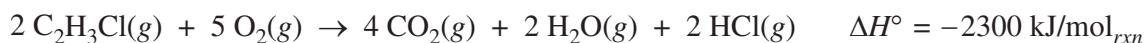
Propene



Vinyl Chloride (chloroethene)

- (b) The boiling point of liquid propene (226 K) is lower than the boiling point of liquid vinyl chloride (260 K). Account for this difference in terms of the types and strengths of intermolecular forces present in each liquid.

In a separate experiment, the student measures the enthalpies of combustion of propene and vinyl chloride. The student determines that the combustion of 2.00 mol of vinyl chloride releases 2300 kJ of energy, according to the equation below.



- (c) Using the table of standard enthalpies of formation below, determine whether the combustion of 2.00 mol of propene releases more, less, or the same amount of energy that 2.00 mol of vinyl chloride releases. Justify your answer with a calculation. The balanced equation for the combustion of 2.00 mol of propene is $2 \text{C}_3\text{H}_6(g) + 9 \text{O}_2(g) \rightarrow 6 \text{CO}_2(g) + 6 \text{H}_2\text{O}(g)$.

Substance	$\text{C}_2\text{H}_3\text{Cl}(g)$	$\text{C}_3\text{H}_6(g)$	$\text{CO}_2(g)$	$\text{H}_2\text{O}(g)$	$\text{HCl}(g)$	$\text{O}_2(g)$
Standard Enthalpy of Formation (kJ/mol)	37	21	-394	-242	-92	0