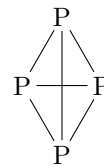


1. What is the P–P bond enthalpy in $P_4(s)$ given the following facts:

- (a) The Cl–Cl bond enthalpy is $338 \frac{\text{kJ}}{\text{mol}}$
 (b) The P–Cl bond enthalpy is $326 \frac{\text{kJ}}{\text{mol}}$
 (c) $\Delta H_f^\circ(\text{PCl}_3(g))$ is $-306.4 \frac{\text{kJ}}{\text{mol}}$



$P_4(s)$ at SATP



$$\Delta H_{\text{rxn}}^\circ = \sum(\text{bonds broken}) - \sum(\text{bonds formed})$$

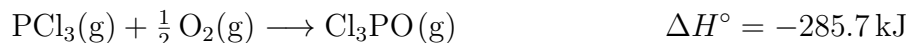
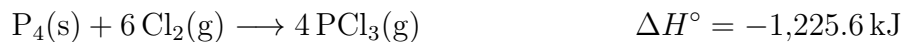
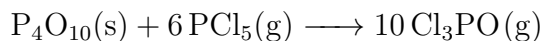
$$4 \cdot \Delta H_f^\circ(\text{PCl}_3) = (6 \cdot 338 \frac{\text{kJ}}{\text{mol}} + 6(\text{P–P})) - 12 \cdot 326 \frac{\text{kJ}}{\text{mol}}$$

$$4 \cdot -306.4 \frac{\text{kJ}}{\text{mol}} = 2,028 \text{ kJ} + 6(\text{P–P}) - 3,912 \text{ kJ}$$

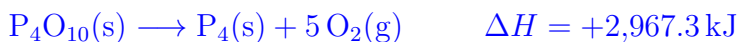
$$6(\text{P–P}) = -1,225.6 \text{ kJ} + 1,884 \text{ kJ}$$

$$\boxed{(\text{P–P}) = 109.7 \frac{\text{kJ}}{\text{mol}}}$$

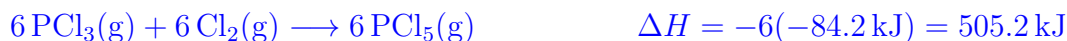
2. Calculate $\Delta H_{\text{rxn}}^\circ$ for the following reaction using the given equations:



(2) must be flipped to get $P_4O_{10}(s)$ as reactant:



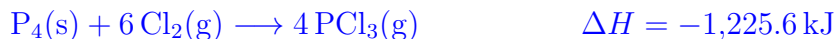
(3) must be $\times(-6)$ to get $6 \text{PCl}_5(g)$ as reactant:



(4) must be $\times(10)$ to get $10 \text{Cl}_3\text{PO}(g)$ as product:



(1) remains untouched cancel out stuff like $6 \text{Cl}_2(g)$:

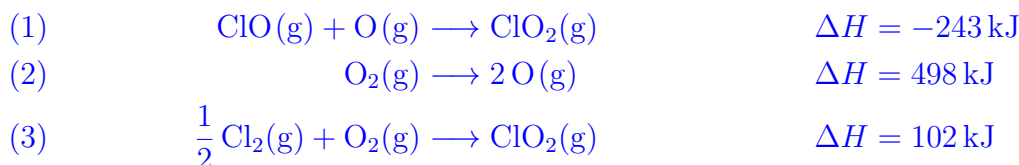


$$\Delta H_{\text{rxn}}^\circ = (2,967.3 \text{ kJ}) + (-505.2 \text{ kJ}) + (-2,857.0 \text{ kJ}) + (-1,225.6 \text{ kJ}) = \boxed{-610.1 \text{ kJ}}$$

3. Find the ΔH_f° of $\text{ClO}(\text{g})$ given the following facts:

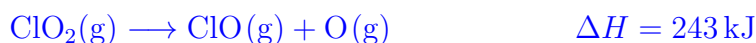
- (a) When one mole of oxygen atoms in the gas phase is added to one mole of $\text{ClO}(\text{g})$, one mole of $\text{ClO}_2(\text{g})$ is formed and 243 kJ of heat is released
- (b) $\text{O}=\text{O}$ bond enthalpy is $498 \frac{\text{kJ}}{\text{mol}}$
- (c) $\Delta H_f^\circ(\text{ClO}_2(\text{g}))$ is $102 \frac{\text{kJ}}{\text{mol}}$

First write out equations corresponding to these statements:



Then do Hess's Law. Our target equation is $\text{Cl}(\text{g}) + \frac{1}{2} \text{O}_2(\text{g}) \longrightarrow \text{ClO}(\text{g})$

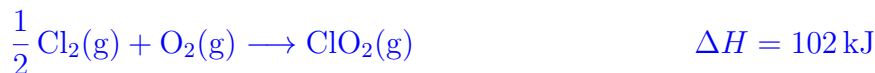
(1) needs to be flipped for $\text{ClO}(\text{g})$:



(2) for needs to be halved, flipped for $\text{O}_2(\text{g})$:

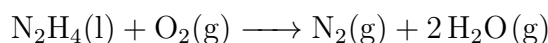


(3) remains unchanged to cancel $\text{ClO}_2(\text{g})$



$$\Delta H_{\text{rxn}}^\circ = (243 \text{ kJ}) + (-249 \text{ kJ}) + (102 \text{ kJ}) = \boxed{96 \text{ kJ}}$$

4. Find the $\Delta H_{\text{rxn}}^\circ$ of this reaction given the following facts:



(a) $\Delta H_f^\circ(\text{H}_2\text{O}(\text{g})) = -241.82 \frac{\text{kJ}}{\text{mol}}$

(b) $\Delta H_f^\circ(\text{N}_2\text{H}_4(\text{l})) = 50.63 \frac{\text{kJ}}{\text{mol}}$

$$\Delta H_{\text{rxn}}^\circ = \sum \Delta H_f^\circ(\text{products}) - \sum \Delta H_f^\circ(\text{reactants})$$

$$\Delta H_{\text{rxn}}^\circ = [\Delta H_f^\circ(\text{N}_2(\text{g})) + 2\Delta H_f^\circ(\text{H}_2\text{O}(\text{g}))] - [\Delta H_f^\circ(\text{N}_2\text{H}_4(\text{l})) + \Delta H_f^\circ(\text{O}_2(\text{g}))]$$

$\Delta H_f^\circ(\text{N}_2(\text{g})) = 0$ and $\Delta H_f^\circ(\text{O}_2(\text{g})) = 0$ since elements in their standard state

$$\begin{aligned} \Delta H_{\text{rxn}}^\circ &= [0 + 2(-241.82 \frac{\text{kJ}}{\text{mol}})] - [50.63 \frac{\text{kJ}}{\text{mol}} + 0] \\ &= \boxed{-534.27 \text{ kJ}} \end{aligned}$$

Homework Problem 15

1. Find the bond enthalpy of an bond given the following facts:

(a) $\Delta H_f^\circ(\text{H}_2\text{O}(\text{g})) = -241.8 \frac{\text{kJ}}{\text{mol}}$

(b) $\Delta H_f^\circ(\text{O}(\text{g})) = 249.2 \frac{\text{kJ}}{\text{mol}}$

(c) H-H bond enthalpy is $435 \frac{\text{kJ}}{\text{mol}}$