# Example 1

Suppose the gas in Figure is 0.1 mol He at 298 K, the two weights correspond to an external pressure of 2.40 atm in Figure (a), and the single weight in Figure (b) corresponds to an external pressure of 1.20 atm. How much work, in joules, is associated with the <u>gas expansion</u> at constant temperature?

$n = 0.1$ mol
$T = 298$ K
$P_1 = 2.40$ atm
$P_2 = 1.2$ atm
$w = ?$ j
$R = 0.0821$

V_1 ?
V_2 ?

$$w = -P_{ext} \Delta V$$

① finding V_1

$$P_1 V_1 = nRT$$

$$V_1 = \frac{nRT}{P_1} = \frac{0.1 \times 0.0821 \times 298}{2.4} = 1.02 \text{ L}$$

② Finding V_2 $P_1 V_1, P_2, V_2$?

$$P_1 V_1 = P_2 V_2$$

$$V_2 = \frac{P_1 V_1}{P_2} = \frac{2.4 \times 1.02}{1.2} = \underline{2.04 \text{ L}} \quad \text{to convert to } j$$

③ $w = -P\Delta V = -1.2 \times (V_2 - V_1)$

$$= -1.2 \times \underline{(2.04 - 1.02) \times 101} \text{ j} = \underline{\underline{1.24 \times 10^2 \text{ j}}}$$

Example 2

- How much work is done, in joules, when an external pressure of 2.50 atm is applied, at a constant temperature of 20.0 °C, to 50.0 g $N_2(g)$ in a 75.0 L cylinder? (The cylinder is like that shown in the Figure given example 4.) } 2.5

$W = ? \ j$

$m = 50 \ g$

$V_1 = 75 \ L$

$T = 20 + 273 = 293 \ K$

$P_2 = 2.5 \ atm$

P_i : $\}$ → ▷

V_2
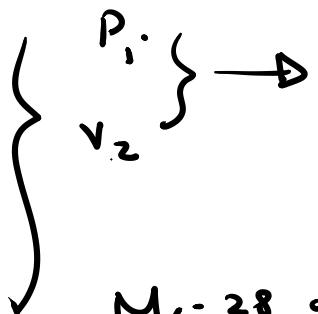
$M_r = 28 \ g/mol.$

① Finding ⓟ₁

$PV_1 = nRT$

$P_1 = \dfrac{nRT}{V} = \dfrac{50 \times 0.0821 \times 293}{28 \times 75}$

$= 0.58 \ atm$

② Finding ⓥ₂

$P_1 V_1 = P_2 V_2$

$V_2 = \dfrac{P_1 V_1}{P_2} = \dfrac{0.58 \times 75}{2.5}$

$= 17.4 \ L$

③ $W = -P_{ext} \Delta V$

$= -2.5 \times (17.5 - 75) \times 101 = 14.5 \ j$

Example 3

$1 \text{ atm} = 760 \text{ mmHg}$
$= 760 \text{ torr}$

How much work is done, in joules (J), when an expanding from 2.15 atm to 746 mmHg is applied, at a constant temperature of 23 °C, to 0.225 mol N_2(g) in a piston cylinder?

$= 101.325 \text{ KPa}$

$w = ? \text{ j}$

$P_1 = 2.15 \text{ atm}$

$P_2 = \dfrac{746}{760} \text{ mmHg} = 0.98 \text{ atm}$

$T = 23°C + 273 = 296 \text{ K}$

$n = 0.225 \text{ mol}$

① finding V_1

$P_1 V_1 = n RT$

$V_1 = \dfrac{nRT}{P_1} = \dfrac{0.225 \times 0.08821 \times 296}{2.15}$

$V_1 = 2.54 \text{ L}$

② Finding V_2

$P_1 V_1 = P_2 V_2$

$V_2 = \dfrac{P_1 V_1}{P_2} = \dfrac{2.15 \times 2.54}{0.98}$

$= 5.57 \text{ L}$

③ $w = -P_{ext} \Delta V$

to convert to j

$= -0.98 \times (5.57 - 2.54)^{\times 101} = -300.80 \text{ j}$

$$w = -P_{ext} \Delta v$$
$$\Delta U = q + w$$

Example 4

- A gas, while expanding, absorbs 25 J of heat and does 243 J of work. What is for the gas?
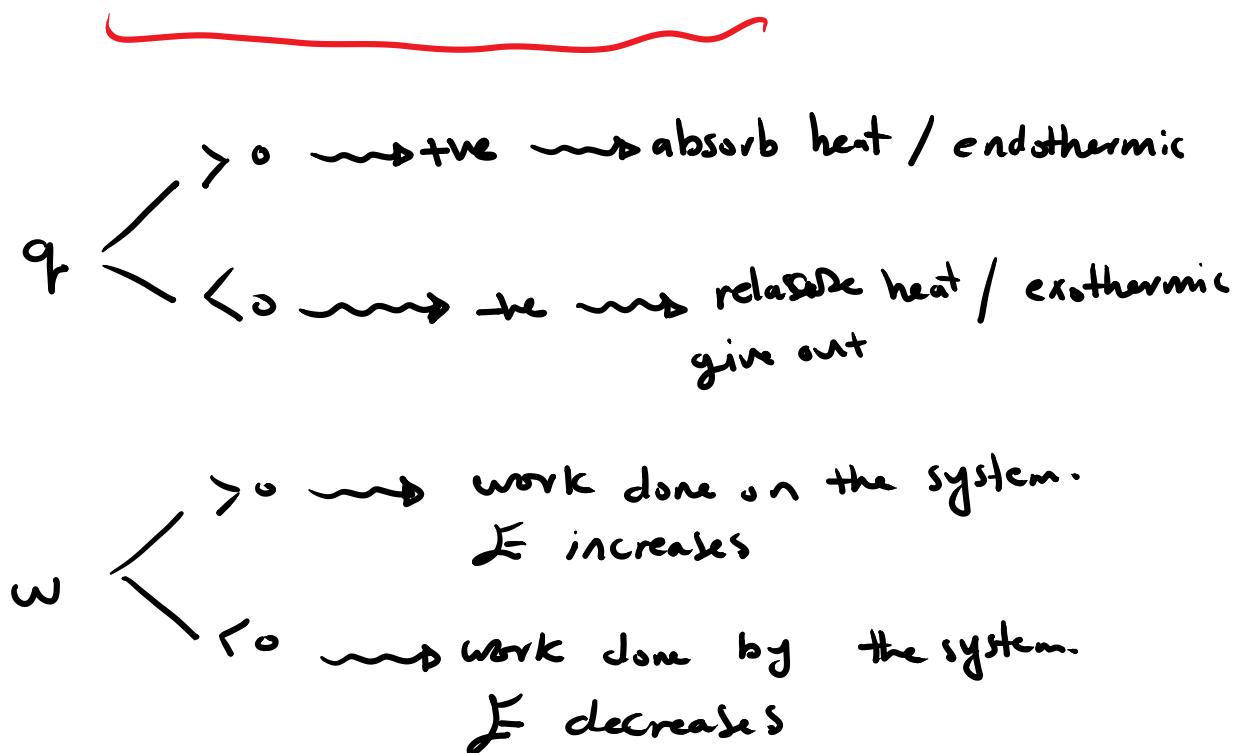
$$q = +25 \text{ j}$$
$$w = -245 \text{ j}$$

$$\Delta U = q + w$$
$$= +25 - 245 = -218 \text{ j}$$

$$q \begin{cases} > 0 \rightsquigarrow +ve \rightsquigarrow \text{absorb heat / endothermic} \\ < 0 \rightsquigarrow -ve \rightsquigarrow \text{release heat / exothermic} \\ \qquad\qquad\qquad\quad \text{give out} \end{cases}$$

$$w \begin{cases} > 0 \rightsquigarrow \text{work done on the system.} \\ \qquad\qquad E \text{ increases} \\ < 0 \rightsquigarrow \text{work done by the system.} \\ \qquad\qquad E \text{ decreases} \end{cases}$$

Example 5

$x \div \sim$

inverse $\sim$

$3 \times$

$4 \times$

$$C_3H_8(g) + 5O_2(g) \longrightarrow 3CO_2(g) + 4H_2O(l) \qquad \Delta H° = -2219.9 \text{ kJ}$$
$$C(\text{graphite}) + O_2(g) \longrightarrow CO_2(g) \qquad \Delta H° = -393.5 \text{ kJ} \times 3$$
$$H_2(g) + \frac{1}{2}O_2(g) \longrightarrow H_2O(l) \qquad \Delta H° = -285.8 \text{ kJ} \times 4$$
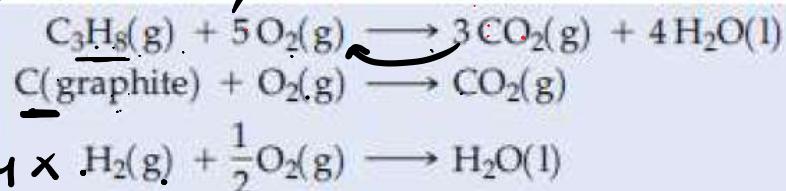
Determine ΔH for the reaction given below

$$3\,C(\text{graphite}) + 4\,H_2(g) \longrightarrow C_3H_8(g) \qquad \Delta H° = ?$$

$3C + \cancel{3O_2} \longrightarrow 3CO_2 \qquad\qquad \Delta H = -393.5 \times 3$

$4H_2 + \cancel{2O_2} \longrightarrow 4H_2O \qquad\qquad \Delta H \quad -285.8 \times 4$

$3CO_2 + 4H_2O \longrightarrow C_3H_8 + \cancel{5O_2} \qquad \Delta H = +2219.9$

$3C + 4H_2 \longrightarrow C_3H_8$
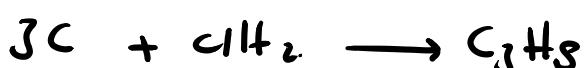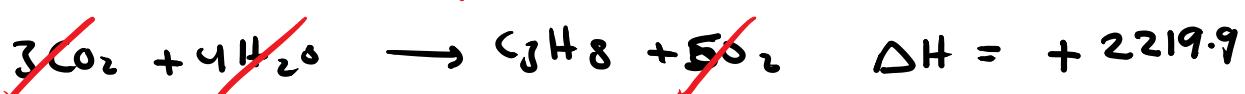
$\Delta H = -393.5 \times 3 + (-285.8 \times 4) + 2219.9$

$\quad = -103.8 \text{ kJ}$

Example 6

$- \boxed{+O_2 \longrightarrow CO_2 + H_2O}$

• Calculate the standard enthalpy of combustion of ethane, C_2H_6 (g), a component of natural gas.

$(\Delta Hf°[C_2H_6(g)]=-84.7 \text{ kJ/mol}; \Delta Hf°[CO_2(g)]=-393.5 \text{ kJ/mol}; \Delta Hf°[H_2O(l)]= -285.8 \text{ kJ/mol})$

H_2
O_2
N_2
F_2
Br_2
I_2

$\Delta H = °$

$$\Delta H°_{rxn} = \sum n\Delta H_P - \sum n\Delta H_R$$

$2\times \qquad C_2H_6 + \frac{7}{2}O_2 \longrightarrow 2CO_2 + 3H_2O$

$2C_2H_6 + 7O_2 \longrightarrow 4CO_2 + 6H_2O$

$\qquad\qquad\qquad R \qquad\qquad\qquad\qquad P$

$$\Delta H_{vxn} = \left[(6 \times -285.8) + (4 \times -393.5) \right] -$$
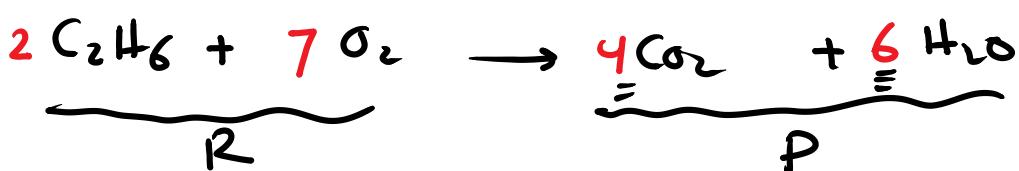
$$\left[(0 + 2 \times -84.7) \right]$$

$$= -3018.6 \text{ kJ}$$

The overall reaction that occurs in photosynthesis in plants is

$$6 \; CO_2(g) + 6 \; H_2O \; (l) \rightarrow C_6H_{12}O_6 \; (s) + 6 \; O_2(g) \qquad \Delta H° = \text{-6535 kJ}_{rxn}$$

Calculate the $\Delta Hf°[C_6H_{12}O_6 \; (s)]$.

($\Delta Hf°[CO_2(g)]$= -393.5 kJ/mol; $\Delta Hf°[H_2O(l)]$= -285.8 kJ/mol)
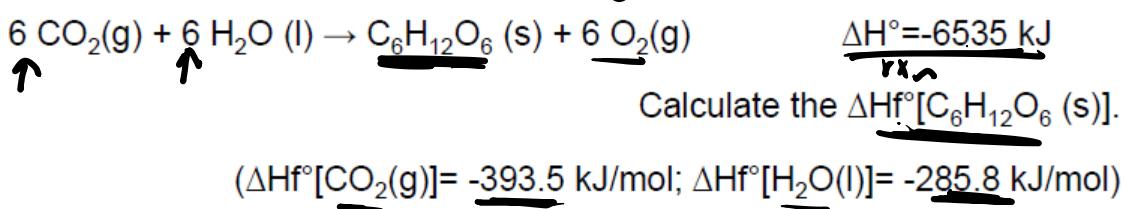
$$\Delta H_{vxn} = \sum n\Delta H_p - \sum n\Delta H_R$$

$$= -4075$$

$$-6535 = \Delta H[C_6H_{12}O_6] - \left[(6 \times -285.8) + (6 \times -393.5) \right]$$

$$\Delta H_{C_6H_{12}O_6} = -4075 - 6585 = -10660.8 \text{ kJ}$$

Example 7

Given that $\Delta H_f°[BaSO_4(s)] = -1473$ kJ/mol, what is the standard enthalpy change for the precipitation of barium sulfate?

$$Ba^{2+}(aq) + SO_4^{2-}(aq) \longrightarrow BaSO_4(s) \qquad \Delta H° = ?$$

($\Delta Hf°[Ba^{2+}(aq)]$= -537.6 kJ/mol; $\Delta Hf°[SO_4^{2-}(aq)]$= -909.3 kJ/mol)

$$\Delta H_{rxn} = (-1473) - (-909.3 - 537.6)$$

$$= -29.1 \text{ kJ}$$

$$\Delta H_{rxn} = \sum n\Delta H_p - \sum n\Delta H_R = \Delta H_{BaSO_4} - (\Delta H_{SO_4} + \Delta H_{Ba^+})$$

Practice makes perfect ! ☺

Given that ΔHf°[AgI(s)]= -61.84 kJ/mol, what is the standard enthalpy change for the precipitation of silver iodide?

$$Ag^+ + I^- \longrightarrow \underline{AgI}$$

+105.6   -61.84
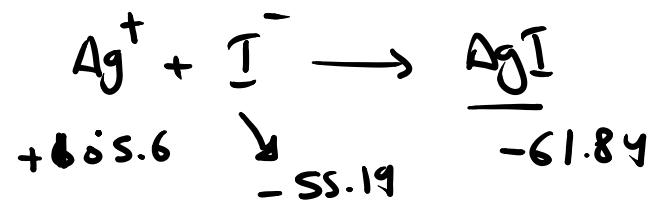
-55.19

$$\Delta H_{rxn} = (+61.84) - (+105.6 \; . -55.19 \;)$$

$$= 112 \cdot 25 \; kJ$$