السنة الثالثة ثانوي شعبة تقني رياضي فرع هندسة الطرائق

حلول سلسلة التمارين في الديناميكا الحرارية

التمـــــرين - 1- :

PV = nRT : n = 1mol , T = 273K , P = 1atm = 1,013 bar = $1,013.10^5$ Pa , V = 22,4 L

PV = nRT => R = PV/nRT => R = $1,013.10^5$ Pa . $22,4.10^{-3}m^3$ / 1mol . 273K = **8,31 J/mol.K** (1J= 1Pa. m^3)

PV = nRT => R = PV/nRT => R = 1atm . 22,4L / 1mol . 273K = **0,082 L.atm/mol.K**

R = 8,31 J/mol.K et (1cal= 4,18 joul) => R = 8,31/4,18 = **2 cal/mol.K**

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التمـــــرين - 2- :

1) T= Cste => $T_2 = T_1$ = **298 K**

2) $\Delta U = n.C_v.\Delta T$ et ($\Delta T = 0$) => **$\Delta U = 0$**

3) W = - intégrl PdV et T= Cste => $W = nRT.\ln(P_2/P_1)$ => $W = 1mol.8,31.298.\ln(1/5)$ = **-3985,6 J**

4) $\Delta U = W + Q$, $\Delta U = 0$ => Q = -W = **3985,6 J**

5) $\Delta H = n.C_p.\Delta T$ et ($\Delta T = 0$) => **$\Delta H = 0$**

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التمـــــرين - 3- :

1) $m = m_{HCl} + m_{NaOH}$ = 0,1.2.36,5 + 0,1.2.40 = 15,3 g = **0,0153 kg**

2) $Q = (m.Cp_{solution} + C_{calorimtr}).\Delta T$ = (0,0153kg . 4180J/Kg.K + 200 J/K) . (43K) = **11350 J**

3) $n_{HCl} = n_{NaOH}$ = 0,1.2 = 0,2 mol => Q' = Q/0,2 = 11350/0,2 = **56750 J**

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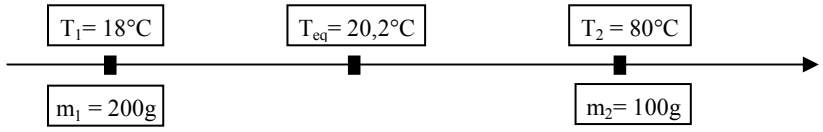
التمـــــرين - 4- :



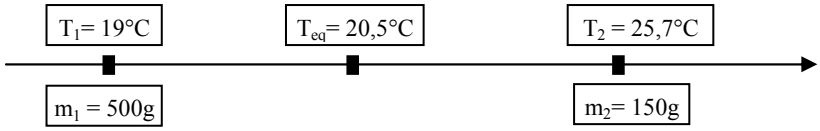
$Q_{\text{المكتسبة}} = Q_{\text{المحررة}}$ => $(m_1.Cp_{eau} + C_{calorimtr}).\Delta T_1 = m_2.\mathbf{Cp_{cuivre}}.\Delta T_2$

=> $(m_1.Cp_{eau} + C_{calorimtr}).(T_{eq} - T_1) = m_2.\mathbf{Cp_{cuivre}}.(T_2 - T_{eq})$

=> $(0,2kg.4180J/kg.K + 200J/K).(293,2K - 291K) = (0,1kg.\mathbf{Cp_{cuivre}}).(353K - 293,2K)$ => Cp_{cuivre} = **381 $J.Kg^{-1}.K^{-1}$**

التمـــــرين - 5- :

.1

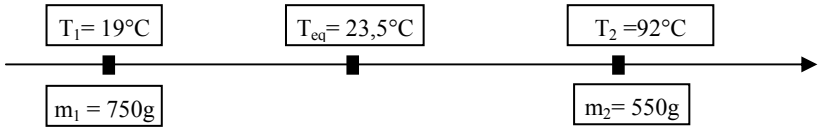


$Q_{\text{المكتسبة}} = Q_{\text{المحررة}} \Rightarrow (m_1.Cp_{eau} + \mathbf{C_{calorimtr}}).\Delta T_1 = m_2.Cp_{eau}.\Delta T_2 \Rightarrow (m_1.Cp_{eau} + C_{calorimtr}).(T_{eq} - T_1) = m_2.Cp_{eau}.(T_2 - T_{eq})$

$\Rightarrow$ $(0,5kg.4180J/kg.K + \mathbf{C_{calorimtr}}).(293,5K - 292K) = (0,15kg.\ 4180J/kg.K).(298,7K - 293,5K)$

$\Rightarrow$ $C_{calorimrte}$ **= 83,3 J.K^{-1}**

.2

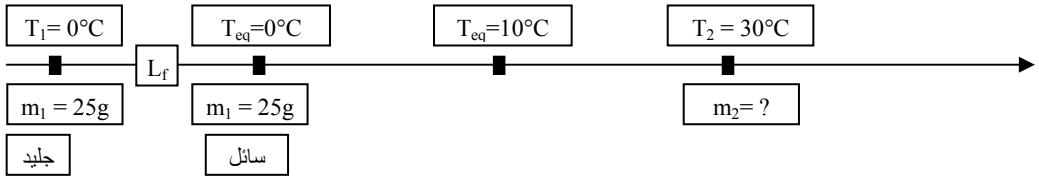


$Q_{\text{المكتسبة}} = Q_{\text{المحررة}} \Rightarrow (m_1.Cp_{eau} + C_{calorimtr}).\Delta T_1 = m_2.Cp_{cuivre}.\Delta T_2 \Rightarrow (m_1.Cp_{eau} + C_{calorimtr}).(T_{eq} - T_1) = m_2.Cp_{cuivre}.(T_2 - T_{eq})$

$\Rightarrow$ $(0,75kg.4180J/kg.K + 83,3J/K).(296,5K - 292K) = (0,55kg.\mathbf{Cp_{cuivre}}).(365K - 296,5K)$

$\Rightarrow$ Cp_{cuivre} = **384,4 J.Kg^{-1}.K^{-1}**

.3



$Q_{\text{المكتسبة}} = Q_{\text{المحررة}} \Rightarrow m_1.L_f + m_1.Cp_{eau}.(T_{eq} - T_1) = m_{soda}.Cp_{soda}.(T_2 - T_{eq})$

$\Rightarrow$ $0,025kg.335.10^{+3}\ J/kg + 0,025kg.4180J/kg.K.(283K - 273K) = m_{soda}.\ 4180J/kg.K\ .\ (303K - 283K)$

$\Rightarrow$ m_{soda} = **112,7 g**

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التمـــــرين - 6- :

$C_{(s)} + 2\ H_{2(g)} + 1/2\ O_{2(g)} \Rightarrow CH_3OH_{(l)}$ $\quad \Delta H°_1 = +\ 638,8\ kJ$

$C_{(s)} + O_{2(g)} \Rightarrow CO_{2(g)}$ $\quad \Delta H°_2 = -\ 393,5\ kJ$

$H_{2(g)} + 1/2\ O_{2(g)} \Rightarrow H_2O_{(g)}$ $\quad \Delta H°_3 = -\ 241,8\ kJ$

$CH_3OH_{(l)} + 3/2\ O_{2(g)} \Rightarrow CO_{2(g)} + 2\ H_2O_{(g)}$ $\quad \Delta°H_r$

$\Delta H°_r = \Delta H°_{f(CO2)} + 2\Delta H°_{f(H2O)} - \Delta H°_{f(CH3OH)} - 3/2\Delta H°_{f(O2)} = \Delta H°_2 + 2\Delta H°_3 - \Delta H°_1$ = **-1515,9 kJ/mol**

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التمـــــرين - 7- :

$\Delta H°_r = \Delta H°_1 - \Delta H°_2 = -\ 241,8 - (-\ 285,9) \Rightarrow \Delta H°_r$ **= + 44,1 kJ/mol**

التمـــرين -8- :

$$C_3H_{8\,(g)} + 5O_{2\,(g)} \rightarrow 3CO_{2\,(g)} + 4H_2O_{\,(g)}$$

$3\,C_{(s)} + 4\,H_{2\,(g)} \Longrightarrow C_3H_{8\,(g)}$ $\quad \Delta H°_1 = -103{,}8$ kJ/mol de C_3H_8

$C_{(s)} + O_{2\,(g)} \Longrightarrow CO_{2\,(g)}$ $\quad \Delta H°_2 = -393{,}5$ kJ/mol de CO_2

$H_{2\,(g)} + 1/2\,O_{2\,(g)} \Longrightarrow H_2O_{\,(g)}$ $\quad \Delta H°_3 = -241{,}8$ kJ/mol de H_2O

$C_3H_{8\,(g)} + 5O_{2\,(g)} \rightarrow 3CO_{2\,(g)} + 4H_2O_{\,(g)}$ $\quad \Delta H°_r = 3\Delta H°_2 + 4\Delta H°_3 - \Delta H°_1 \Rightarrow \Delta H°_r =$ **-2043,9 kJ/mol**

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التمـــرين -9- :

$SO_{3\,(g)} + H_2O_{\,(l)} \Longrightarrow H_2SO_{4\,(l)}$ $\quad \Delta H°_1 = -80$ kJ/mol

$S_{(s)} + 3/2\,O_{2\,(g)} \Longrightarrow SO_{3\,(g)}$ $\quad \Delta H°_2 = -395$ kJ/mol

$H_{2\,(g)} + O_{2\,(g)} \Longrightarrow H_2O_{\,(l)}$ $\quad \Delta H°_3 = -286$ kJ/mol

$\Delta H°_1 = \Delta H°_{f\,(H2SO4)} - \Delta H°_2 - \Delta H°_3 \Rightarrow \Delta H°_{f(H2SO4)} = \Delta H°_1 + \Delta H°_2 + \Delta H°_3 =$ **- 761 kJ/mol**

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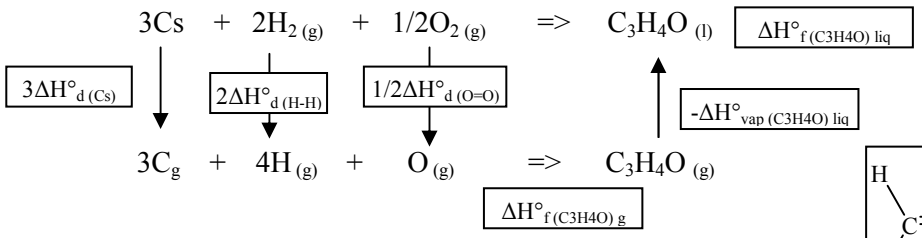
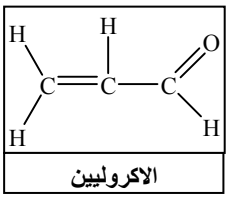
التمـــرين -10- :

$$C_3H_4O_{\,(l)} + 7/2O_{2\,(g)} \rightarrow 3CO_{2\,(g)} + 2H_2O_{\,(l)}$$

1) $\Delta H°_{r(C3H4O)\,liq} = 3\Delta H°_{f\,(CO2)} + 2\Delta H°_{f\,(H2O)} - \mathbf{\Delta H°_{f\,(C3H4O)}} - 7/2/2\Delta H°_{f\,(O2)} \Rightarrow \Delta H_{f\,(C3H4O)\,liq} =$ **- 121,1 kJ/mol**

2)





$\Delta H_{f\,(C3H4O)\,liq} = 3\Delta H°_{sub\,(Cs)} + 2\Delta H°_{d\,(H-H)} + 1/2\Delta H°_{d\,(O=O)} + \Delta H_{f\,(C3H4O)\,g} - \Delta H_{vap\,(C3H4O)\,liq}$

$\Delta H°_d = -E \Rightarrow \Delta H_{f\,(C3H4O)\,liq} = 3\Delta H°_{sub\,(Cs)} - 2E_{(H-H)} - 1/2E_{(O=O)} + \Delta H_{f\,(C3H4O)\,g} - \Delta H_{vap\,(C3H4O)\,liq}$

$\Delta H_{f\,(C3H4O)\,g} = E_{C=C} + E_{C-C} + 4E_{C-H} + E_{C=O} =$ -3340 kJ/mol $\Rightarrow \Delta H_{f\,(C3H4O)\,liq} =$ **- 91,8 kJ/mol**

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التمـــرين - 11- :

$CO_{\,(g)} + 1/2O_{2\,(g)} \rightarrow CO_{2\,(g)}$ $\quad \Delta H°_{r,298K\,(1)} = -283$ kJ

$H_{2\,(g)} + 1/2O_{2\,(g)} \rightarrow H_2O_{\,(g)}$ $\quad \Delta H°_{r,\,298K\,(2)} = -241,8$ kJ

$CH_{4\,(g)} + 2O_{2\,(g)} \rightarrow CO_{2\,(g)} + 2H_2O_{\,(g)}$ $\quad \Delta H°_{r,\,298K\,(3)} = -803,2$ kJ

$CO_{\,(g)} + 3\,H_{2\,(g)} \Longrightarrow CH_{4\,(g)} + H_2O_{\,(g)}$ $\quad \Delta H°_{r,298K} = \Delta H°_{r,298K\,(1)} + 3\,\Delta H°_{r,\,298K\,(2)} - \Delta H°_{r,\,298K\,(3)}$

$\Rightarrow \Delta H°_{r,298K} =$ **-205,2 kJ**

$\Delta U°_{r,298K} = \Delta H°_{r,298K} - \Delta n_g.RT$, $\Delta n_g = (1+1) - (3+1) = -2 \Rightarrow \Delta U°_{r,298K} = -205{,}2 - (-2)(8{,}31.10^{-3}).(298)$

$\Rightarrow \Delta U°_{r,298K} =$ **-200,24 kJ**

$\Delta H°_{r,298K} =$ **-205,2 kJ < 0 => réaction exothermique (تفاعل ناشر للحرارة)**

التمـــــرين - 12 :

$$C_2H_2O_4\ (s) + 1/2\ O_2\ (g) \rightarrow 2\ CO_2\ (g) + H_2O\ (l) \quad \text{à} \quad 298K$$

$\Delta H°_r = n_i.\Delta H°_f(\text{produits}) - n_j.\Delta H°_f(\text{réactifs})$ بتطبيق قانون هس

$$\Delta H°_{r\ (C2H2O4,\ s)} = 2\Delta H°_{f\ (CO2,\ g)} + \Delta H°_{f\ (H2O,\ l)} - \Delta H°_{f\ (C2H2O4,\ s)} - 1/2\ \Delta H°_{f\ (O2\ (g))}$$

$$\Rightarrow \quad \Delta H°_{r\ (C2H2O4,\ s)} = \mathbf{751\ kJ.mol^{-1}}$$

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التمـــــرين - 13 :

$C_2H_6\ (g) + 7/2O_2\ (g) \Longrightarrow 2CO_2\ (g) + 3H_2O\ (l) \qquad \Delta H°_{r,298} = -373,8$ kcal

$\Delta H°_r = n_i.\Delta H°_f(\text{produits}) - n_j.\Delta H°_f(\text{réactifs})$ بتطبيق قانون هس

$$\Delta H°_{r\ (C2H6\ (g))} = 2\Delta H°_{f\ (CO2,\ g)} + 3\Delta H°_{f\ (H2O,\ l)} - \Delta H°_{f\ (C2H6(\ g))} - 7/2\ \Delta H°_{f\ (O2\ (g))}$$

$$\Rightarrow \Delta H°_{f\ (C2H6(\ g))} = 2\Delta H°_{f\ (CO2,\ g)} + 3\Delta H°_{f\ (H2O,\ l)} - \Delta H°_{r\ (C2H6\ (g))} = \mathbf{-19,2\ kcal.mol^{-1}}$$

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التمـــــرين - 14 :

$$N_2\ (g) + 3\ H_2\ (g) \rightarrow 2NH_3\ (g) \qquad \Delta H°_{r,298} = -22,08 \text{ kcal}$$

$Cp\ (N_2,g) = 6,85 + 0,28.10^{-3}\ T$
$Cp\ (NH_3,g) = 5,72 + 8,96.10^{-3}\ T$
$Cp\ (H_2,g) = 6,65 + 0,52.10^{-3}\ T$

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$$\Rightarrow \quad \mathbf{\Delta H°_T = -18,22 - 15,36.10^{-3}\ T + 8,04.10^{-6}\ T^2\ kcal.}$$

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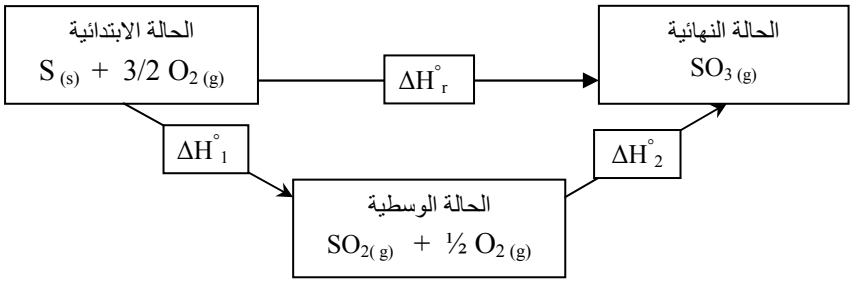
التمـــــرين - 15 :

1. مخطط التفاعل



$$\Delta H°_r = \Delta H°_1 + \Delta H°_2 \Rightarrow \Delta H°_2 = \Delta H°_r - \Delta H°_1 = -94,48 - (-70,96) = \mathbf{-23,52\ kcal}$$

2. <u>الطاقة الداخلية</u>

$$\mathbf{CaCO_{3\ (S)} \rightarrow CaO_{(S)} + CO_{2\ (g)}} \Rightarrow \Delta H°_r = \Delta H°_{f\ (CO2,\ g)} + \Delta H°_{f,(\ CaO\ (S))} - \Delta H°_{f\ (CaCO3\ (S))} = \mathbf{23,7\ kcal}$$

$\Delta U = \Delta H° - \Delta n_g.RT$, $\Delta n_g = 1 \Rightarrow \Delta U°_{r,298K} = 23,7 - (1)(2.10^{-3}).(273) = \mathbf{23,15\ kcal}$

التمـــــرين - 16 - :

$$C_2H_{4(g)} + 3O_{2(g)} \rightarrow 2CO_{2(g)} + 2H_2O_{(l)} \quad \Delta H°_{r,298} = -1387,8 \text{ kJ/mol}$$

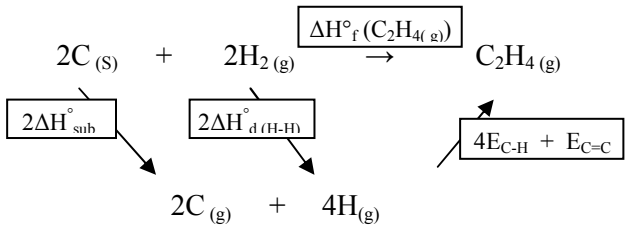
1.

$\Delta H°_r = \sum n_i.\Delta H°_f \text{ (produits)} - \sum n_j.\Delta H°_f \text{ (réactifs)}$ بتطبيق قانون هس

$\Delta H°_{r\ (C2H4\ (g))} = 2\Delta H°_{f\ (CO2,\ g)} + 2\Delta H°_{f\ (H2O,\ l)} - \Delta H°_{f\ (C2H4(\ g))} - 3\Delta H°_{f,(O2\ (g))}$

$\Delta H°_{f\ (C2H4(\ g))} = 2\Delta H°_{f\ (CO2,\ g)} + 2\Delta H°_{f\ (H2O,\ l)} - \Delta H°_{r\ (C2H4\ (g))} =$ **$33,6 \text{ kJ.mol}^{-1}$**

2.



$\Delta H°_{f\ (C2H4(\ g))} = 2\Delta H°_{sub\ (CS)} + 2\Delta H°_{d\ (H-H)} + 4E_{C-H} + E_{C=C}$; $(\Delta H°_{d\ (H-H)} = -E_{(H-H)})$

=> $E_{C=C} = \Delta H°_{f\ (C2H4(\ g))} - 2\Delta H°_{sub\ (CS)} + 2E_{(H-H)} - 4E_{C-H}$ => **$E_{C=C} = -611,83 \text{ kJ.mol}^{-1}$**

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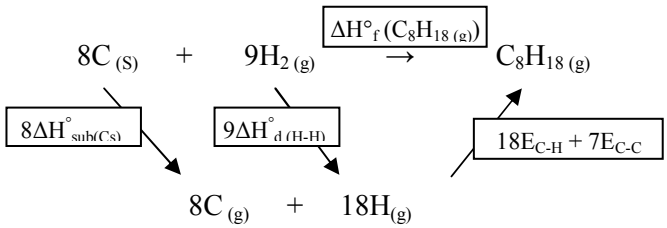
التمـــــرين - 17 - :



1. حساب الأنطالبي المعيارية لتشكل الأوكتان الغازي عند 298 K:

$\Delta H°_{f\ (C8H18\ (g))} = 8\Delta H°_{sub\ (CS)} + 9\Delta H°_{d\ (H-H)} + 18E_{C-H} + 7E_{C-C}$

$\Delta H°_{f\ (C8H18\ (g))} = 8.716,7 + 9.436 + 18.(-415) + 7.(-345)$ => **$\Delta H°_{f\ (C8H18\ (g))} = -227,4 \text{ kJ/mol}$**

2. حساب الأنطالبي المعيارية لاحتراق الأوكتان الغازي:

$$C_8H_{18\ (g)} + 25/2O_{2(g)} \rightarrow 8CO_{2(g)} + 9H_2O_{(l)}$$

$\Delta H°_r = \sum n_i.\Delta H°_f \text{ (produits)} - \sum n_j.\Delta H°_f \text{ (réactifs)}$ بتطبيق قانون هس

$\Delta H°_{comb\ (C8H8\ (g))} = 8\Delta H°_{f,\ (CO2(g))} + 9\Delta H°_{f,\ (H2O(g))} - \Delta H°_{f,\ (C8H8\ (g))} - 25/2\Delta H°_{f,\ (O2\ (g))}$

$\Delta H°_{comb\ (C8H8\ (g))} = 8.(-393,5) + 9.(-241,83) - (-227,4) - 0 =$ **$-5093,2 \text{ kJ/mol}$**

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التمـــرين 18:

- معادلة الاحتراق:

$$CH_3\text{-}CHOH\text{-}COOH_{(l)} + 3O_{2(g)} \rightarrow 3CO_{2(g)} + 3H_2O_{(l)}$$

$C_3H_6O_3$ => $M = 90$ g/mol => $n = 18/90 = 0,2$ mol

معناه الأنطالبية القياسية لإحتراق 1mol من الحمض هي: $\Delta H°_{comb} = -272,54 \cdot 5 = -1362,7$ kJ/mol

$\Delta H°_{f\ (C3H6O3)} = 3\Delta H°_{f\ (CO2,\ g)} + 3\Delta H°_{f\ (H2O,\ l)} - \Delta H°_{r\ (C3H6O3)} =$ **$-686,72 \text{ kJ/mol}$**

التمـرين 19:

1. حساب $\Delta H°_{r,298}$ للتفاعل:

$$C_2H_5OH_{(g)} \Longrightarrow CH_2=CH_{2\,(g)} + H_2O_{(g)} \qquad \Delta H°_{r,298} = ?$$

$\Delta H°_1$: $C_2H_5OH_{(g)} \rightarrow 2C_{(g)} + 6H_{(g)} + O_{(g)}$

$\Delta H°_2$: $CH_2=CH_{2\,(g)} + H_2O_{(g)} \rightarrow 2C_{(g)} + 6H_{(g)} + O_{(g)}$

باستعمال قانون طاقات الربط:

$$\Delta H°_{r,298} = \Delta H°_1 + \Delta H°_2 = (5\Delta H°_{d,C-H} + \Delta H°_{d,C-C} + \Delta H°_{d,C-O} + \Delta H°_{d,O-H}) + (E_{C=C} + 4E_{C-H} + 2E_{O-H})$$
$$= (-5E_{C-H} - E_{C-C} - E_{C-O} - E_{O-H}) + (E_{C=C} + 4E_{C-H} + 2E_{O-H}) = \mathbf{+ 71,4\ kJ/mol}$$

2. حساب طاقة الرابطة C-F للتفاعل التالي:

$$CH_{4\,(g)} + 4F_{2\,(g)} \Longrightarrow CF_{4\,(g)} + 4HF_{(g)} \qquad \Delta H°_{r,298} = -1923\ kJ/mol$$

$\Delta H°_1$: $CH_{4\,(g)} + 4F_{2\,(g)} \rightarrow C_{(g)} + 4H_{(g)} + 8F_{(g)}$

$\Delta H°_2$: $CF_{4\,(g)} + 4HF_{(g)} \rightarrow C_{(g)} + 4H_{(g)} + 8F_{(g)}$

باستعمال قانون طاقات الربط:

$$\Delta H°_{r,298} = \Delta H°_1 + \Delta H°_2 = (4\Delta H°_{d,C-H} + 4\Delta H°_{d,F-F}) + (4E_{C-F} + 4E_{H-F})$$
$$\Delta H°_{r,298} = (-4E_{C-H} - 4E_{F-F}) + (4E_{C-F} + 4E_{H-F}) \Rightarrow E_{C-F} = \mathbf{- 481,5\ kJ/mol}$$

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التمـرين 20:

1. حساب أنطالبي التفاعل:

$$2Na_2O_{2\,(s)} \Longleftrightarrow 2Na_2O_{(s)} + O_{2\,(g)} \qquad \Delta H°_{r,298} = ?$$

بتطبيق قانون هس $\Delta H°_r = n_i.\Delta H°_f(\text{produits}) - n_j.\Delta H°_f(\text{réactifs})$

$$\Delta H°_r = 2\Delta H°_{f,(Na2O\,(s))} + \Delta H°_{f,(O2,\,g)} - 2\Delta H°_{f,(Na2O2\,(s))} = \mathbf{190,4\ kJ/mol}$$

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التمـرين 21:

1. حساب الأنطالبي المعياري لتشكل H_2O_2 :

$$2H_{2\,(g)} + O_{2\,(g)} \Longrightarrow 2H_2O_{(l)} \qquad \Delta H°_1 = -136,8\ kcal/mol$$
$$H_2O_{2\,(g)} \Longrightarrow H_2O_{(l)} + \tfrac{1}{2}O_{2\,(g)} \qquad \Delta H°_2 = -23,83\ kcal/mol$$

$$\Delta H°_1 = 2\Delta H°_{f,(H2O,\,l)} - 2\Delta H°_{f,(H2,\,g)} - \Delta H°_{f,(O2,\,g)} \Rightarrow \Delta H°_1 = 2\Delta H°_{f,(H2O,\,l)} \ldots\ldots..(1)$$
$$\Delta H°_2 = \Delta H°_{f,(H2O,\,l)} + \tfrac{1}{2}\Delta H°_{f,(O2,\,g)} - \Delta H°_{f,(H2O2,\,g)} \Rightarrow \Delta H°_2 = \Delta H°_{f,(H2O,\,l)} - \Delta H°_{f,(H2O2,\,g)} \ldots\ldots..(2)$$
$$\Delta H°_{f,(H2O2,\,g)} = (\Delta H°_1)/2 - \Delta H°_2 = (-136,8)/2 - (-23,83) = \mathbf{- 44,57\ kcal/mol}$$

2. حساب حرارة التشكل عند 100°C:

$$\mathbf{H_{2\,(g)} + \tfrac{1}{2}O_{2\,(g)} \Longrightarrow H_2O_{(l)} \quad \Delta H°_{f,373K} = ?}$$

$\mathbf{T(K)} = T(°C) + 273 \Rightarrow T(K) = 100 + 273 = 373\ K$

$\Delta H°_{37}$

$$\Rightarrow \Delta H°_{f,\,373k} = \Delta H°_{f,100K} + [Cp_{H2O\,(l)} - Cp_{H2\,(g)} - \tfrac{1}{2}Cp_{O2\,(g)}] \,.\, (\Delta T)$$
$$\Rightarrow \Delta H°_{f,\,373k} = -68,3 + (18 - 6,89 - 0,5.6,97).10^{-3} \,.\, (373 - 298) \Rightarrow \Delta H°_{f,\,373k} = \mathbf{- 67,73\ kcal/mol}$$