41 = 82

Name: _____

TEST #2

THERMODYNAMICS

1. Each of the following examples involve a change in enthalpy. If the change in enthalpy is positive, label with an A. If the change in enthalpy is negative, label with a B. Do not guess! One mark for a correct response, minus one half mark for an incorrect response!

(3) /10

a) A water in a puddle gradually evaporates
b) A when two particular solutions are mixed together the average temperature decreases
c) A the sublimation of dry ice i.e $CO_2(s) \Longrightarrow CO_2(g)$
d) A $COCl_2(g) \Longrightarrow CO(g) + Cl_2(g)$
e) A the reactants of a reaction have stronger bonds than the products
f) B after a reaction, the forces of attraction between the atoms involved has undergone a net increase
g) B the condensation of any liquid
h) A the formation of benzene from its elements at 25 °C and 1 atmosphere pressure
i) A photosynthesis
j) A the fermentation of glucose to ethyl alcohol plus carbon dioxide i.e. $C_6H_{12}O_6 \Longrightarrow 2C_2H_6O + CO_2$

2. Calculate the change in enthalpy for the combustion reaction of oleic acid ($C_{18}H_{34}O_2$). Use tables and the fact that:

(3) /4

$\Delta H^\circ_{C_{18}H_{34}O_2} = -818.81$ kJ/mol $\quad -818.81\ kJ \times \frac{1\ cal}{4.184\ J} = -195.70\ kcal$

$C_{18}H_{34}O_2(l) + \frac{51}{2}O_2(g) \rightarrow 18CO_2(g) + 17H_2O(l)$

$\Delta H = [18\,\Delta H^\circ_{CO_2(g)} + 17\Delta H^\circ_{H_2O(l)}] - [\Delta H^\circ_{C_{18}H_{34}O_2(l)} + \frac{51}{2}\Delta H^\circ_{O_2(g)}]$

$\Delta H = [18(-94.0\ kcal) + 17(-68.3\ kcal)] - [-195.70\ kcal + \frac{51}{2}(0)]$

$\Delta H = -2657.4$ kcal

or

-11119 kJ

/14

3. The heat of combustion of styrene, $C_8H_8(l)$ is -1060.52 kcal/mol. Use this information and the table of heats of formation to calculate the heat of formation of styrene.

(3)

$$C_8H_8(l) + 10O_2(g) \rightarrow 8CO_2(g) + 4H_2O(l)$$

$$\Delta H = [8\Delta H^\circ_{CO_2(g)} + 4\Delta H^\circ_{H_2O(l)}] - [\Delta H^\circ_{C_8H_8(l)} + 10\Delta H^\circ_{O_2(g)}]$$

4

$$-1060.52\ kcal = [8(-94.0kcal) + 4(-68.3kcal)] - [\Delta H^\circ_{C_8H_8(l)}]$$

$$\Delta H^\circ_{C_8H_8(l)} = 35.32\ kcal$$

4. Calculate the mass of benzene liquid ($C_6H_6(l)$) that can provide 100 kJ of heat through a combustion reaction. Use the table in your text. No need to use Hess' Law.

(3)

$$C_6H_6(l) + \tfrac{15}{2}O_2(g) \rightarrow 6CO_2(g) + 3H_2O(l)$$

$$\Delta H = [6\Delta H^\circ_{CO_2(g)} + 3\Delta H^\circ_{H_2O(l)}] - [\Delta H^\circ_{C_6H_6(l)} + \tfrac{15}{2}\Delta H^\circ_{O_2(g)}]$$

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$$\Delta H = [6(-94.0kcal) + 3(-68.3kcal)] - [(19.8kcal)]$$

$$\Delta H = -788.7kcal$$

$$Q = -\Delta H$$

$$Q = 788.7kcal/mol$$

$$100\ kJ \times \frac{1kcal}{4.184kJ} \times \frac{1mol}{788.7kcal} \times \frac{78.12g}{1mol} = 2.367g$$

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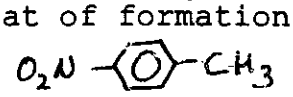
$$7C(s) + \tfrac{7}{2}H_2(g) + O_2(g) + \tfrac{1}{2}N_2(g) \rightarrow C_7H_7O_2N(\ell)$$

5. Use Hess' Law to determine the heat of formation of p-nitrotoluene ($C_7H_7O_2N$) given:



① $C_7H_8(l) + HNO_3(l) \Longrightarrow C_7H_7O_2N(l) + H_2O(l)$ $\Delta H^\circ = -47.25$ kcal

② $C_7H_8(l) + 9O_2(g) \Longrightarrow 7CO_2(g) + 4H_2O(l)$ $\Delta H^\circ = -943.1$ kcal

③ $NO_2(g) + H_2O(l) \Longrightarrow HNO_3(l) + \tfrac{1}{2}H_2(g)$ $\Delta H^\circ = 18.8$ kcal

Table values for the formation reactions of $CO_2(g)$, $H_2O(l)$ and $NO_2(g)$

④ $C(s) + O_2(g) \Rightarrow CO_2(g)$ $\Delta H^\circ = -94.0$ kcal

⑤ $H_2(g) + \tfrac{1}{2}O_2(g) \Rightarrow H_2O(\ell)$ $\Delta H^\circ = -68.3$ kcal

⑥ $\tfrac{1}{2}N_2(g) + O_2(g) \Rightarrow NO_2(g)$ $\Delta H^\circ = +8.1$ kcal

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① $C_7H_8(\ell) + HNO_3(\ell) \Rightarrow C_7H_7O_2N(\ell) + H_2O(\ell)$ $\Delta H^\circ = -47.25$ kcal

③ $NO_2(g) + H_2O(\ell) \Rightarrow HNO_3(\ell) + \tfrac{1}{2}H_2(g)$ $\Delta H^\circ = 18.8$ kcal

rev ② $7CO_2(g) + 4H_2O(\ell) \Rightarrow C_7H_8(\ell) + 9O_2(g)$ $\Delta H^\circ = 943.1$ kcal

7x ④ $7C(s) + 7O_2(g) \Rightarrow 7CO_2(g)$ $\Delta H^\circ = -658.0$ kcal

4x ⑤ $3\tfrac{1}{2}H_2(g) + 2O_2(g) \Rightarrow 4H_2O(\ell)$ $\Delta H^\circ = -273.2$ kcal

⑥ $\tfrac{1}{2}N_2(g) + O_2(g) \Rightarrow NO_2(g)$ $\Delta H^\circ = +8.1$ kcal

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$$7C(s) + \tfrac{7}{2}H_2(g) + O_2(g) + \tfrac{1}{2}N_2(g) \Rightarrow C_7H_7O_2N(\ell) \quad \Delta H^\circ = -8.45 \text{ kcal}$$

$Ca(s) + \frac{1}{2}O_2(g) \Rightarrow CaO(s)$

6. From the following information and Hess' Law, calculate the heat of formation of CaO in kJ

a) $CaO(s) + 2HCl(aq) = CaCl_2(s) + H_2O(l)$

15.00 g of CaO was reacted in 5 L of an HCl solution.* A change in temperature of 19.6°C was noted

b) $Ca(s) + 2HCl(aq) = CaCl_2(s) + H_2(g)$

12.00 g of Ca was reacted in 5 L of an HCl solution.* A change in temperature of 8.7 C was noted.

(3)

c) $H_2(g) + O_2(g) = H_2O(l)$ $\Delta H^\circ = -285.6$ kJ/mol

* consider these solution to have the same heat capacity as water (4.184 J/g°C) and ignore any mass contributions from the addition of CaO and Ca

a) $Q = mc\Delta T$

$Q = 5000g \times 4.184 J/g°C \times 19.6°C$

$Q = 410032 J$

$Q = 410.032 kJ$

$\frac{410.032 kJ}{15.00g CaO} \times \frac{56.08g CaO}{1 mol CaO} = 1533 kJ/mol CaO$

$\Delta H = -Q$

$\Delta H = -1533 kJ/mol CaO$

b) $Q = mc\Delta T$

$Q = 5000g \times 4.184 J/g°C \times 8.7°C$

$Q = 182004 J$

$Q = 182.004 kJ$

$\frac{182.004 kJ}{12.00g Ca} \times \frac{40.08g Ca}{1 mol Ca} = 607.9 kJ/mol Ca$

$\Delta H = -Q$

$\Delta H = -607.9 kJ/mol Ca$

∴ ① $CaO(s) + 2HCl(aq) \Rightarrow CaCl_2(s) + H_2O(l)$ $\Delta H^\circ = -1533$ kJ

② $Ca(s) + 2HCl(aq) \Rightarrow CaCl_2(s) + H_2(g)$ $\Delta H^\circ = -607.9$ kJ

③ $H_2(g) + \frac{1}{2}O_2(g) \Rightarrow H_2O(l)$ $\Delta H^\circ = -285.6$ kJ

new ① $CaCl_2(s) + H_2O(l) \Rightarrow CaO(s) + 2HCl(aq)$ $\Delta H^\circ = 1533$ kJ

② $Ca(s) + 2HCl(aq) \Rightarrow CaCl_2(s) + H_2(g)$ $\Delta H^\circ = -607.9$ kJ

③ $H_2(g) + \frac{1}{2}O_2(g) \Rightarrow H_2O(l)$ $\Delta H^\circ = -285.6$ kJ

$Ca(s) + \frac{1}{2}O_2(g) \Rightarrow CaO(s)$ $\Delta H = +639.5$ kJ

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