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Name: _____

THERMODYNAMICS TEST

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! Wrong subtracted from right!

(7)

a) A The lake thaws slowly in the spring.
b) B When two particular solutions are mixed together the average temperature increases
c) B In a nuclear fission reaction , the total mass of the products is significantly less than the total mass of the reactants.
d) B Sulphuric acid is dissolved in water.
e) B The products of a reaction have greater attractive forces than the reactants.
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 $H_2O(g) + C(s) = CO(g) + H_2(g)$ $\Delta H = 31.4$ kcal
i) A Photosynthesis
j) B The formation of water from its elements at 25 °C and 1 atmosphere pressure.

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2. Use heats of formation directly (i.e. not Hess Law) to calculate the heat of reaction for:

(7)

$$3CuO(s) + 2NH_3(aq) \Longrightarrow 3Cu(s) + 3H_2O(l) + N_2(g)$$

Use your answer to determine:
a) the heat released if 500 g of Cu(s) is recoverd
b) 1.5 L of nitrogen gas is recoverd at S.T.P. (22.414 L of gas = 1 mol of gas)

$\Delta H = [3\Delta H^\circ_{Cu(s)} + 3\Delta H^\circ_{H_2O(l)} + \Delta H^\circ_{N_2(g)}] - [3\Delta H^\circ_{CuO(s)} + 2\Delta H^\circ_{NH_3(aq)}]$ ✓

$\Delta H = [3(0) + 3(-68.3\text{kcal}) + 3(0)] - [3(-37.1\text{kcal}) + 2(-19.3\text{kcal})]$

$\Delta H = -55.0\text{kcal}$ ✓ $\therefore Q = -\Delta H$ ✓

$Q = 55.0\text{kcal}$

a) $500\text{g Cu} \times \frac{1\text{mol Cu}}{63.55\text{g Cu}} \times \frac{55.0\text{kcal}}{3\text{mol Cu}} = 144.24\text{kcal}$ ✓

b) $1.5\text{L } N_2 \times \frac{1\text{mol } N_2}{22.414\text{L } N_2} \times \frac{55.0\text{kcal}}{1\text{mol } N_2} = 3.68\text{kcal}$ ✓

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3. 30 L of water in a bomb calorimeter is warmed from 20.00 °C to 23.94 °C when 10 g of butane (C_4H_{10}) is reacted with sufficient oxygen to allow complete combustion. Use this information plus appropriate heats of formation (i.e. values for carbon dioxide, water and oxygen) to derive the heat of formation for the compound butane. Check this answer with the heat of formation value for butane found in the table to see if the information in the question is correct.

(7)

$Q = mc\Delta T$

$Q = 30\,000\,g \times 4.184\,J/g°C \times 3.94°C$

$Q = 494\,549\,J$

$Q = 494.549\,kJ$

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$$\frac{494.549\,kJ}{10\,g\ C_4H_{10}} \times \frac{58.14\,g\ C_4H_{10}}{1\,mol\ C_4H_{10}} = 2875.307\,kJ/mol\ C_4H_{10}$$

$\Delta H = -Q$

$\Delta H = -2875.307\,kJ/mol\ C_4H_{10}$

$\therefore C_4H_{10}(g) + \frac{13}{2}O_2(g) \rightarrow 4CO_2(g) + 5H_2O(l) \quad \Delta H = -2875.307\,kJ$

$\therefore \Delta H = [4\Delta H^\circ_{CO_2(g)} + 5\Delta H^\circ_{H_2O(l)}] - [\Delta H^\circ_{C_4H_{10}} + \frac{13}{2}\Delta H^\circ_{O_2(g)}]$

$-2875.307\,kJ = [4(-393.1\,kJ) + 5(-285.6\,kJ)] - [\Delta H^\circ_{C_4H_{10}} + {}^{13}/_{2}(0)]$

$\therefore \Delta H^\circ_{C_4H_{10}} = -125.09\,kJ \Rightarrow -29.9\,kcal$

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$\frac{1}{2} N_2 + 2H_2 + \frac{1}{2} Cl_2 \longrightarrow NH_4Cl$

4. Calculate the heat of formation of NH_4Cl using the following equations and Hess' Law (ignore states).

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1.	$NH_3 + HCl == NH_4Cl$	$\Delta H = -176.73$ kJ
2.	$N_2 + 3H_2 == 2NH_3$	$\Delta H = -92.30$ kJ
3.	$2HCl + I_2 == 2HI + Cl_2$	$\Delta H = 236.23$ kJ
4.	$H_2 + I_2 == 2HI$	$\Delta H = 51.80$ kJ

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① ~~NH_3~~ + ~~HCl~~ $\Rightarrow$ NH_4Cl $\Delta H = -176.73$kJ

$\frac{1}{2}$ × ② $\frac{1}{2} N_2 + \frac{3}{2} H_2 \Rightarrow$ ~~NH_3~~ $\Delta H = -46.15$ kJ

rev × $\frac{1}{2}$ × ③ $\frac{1}{2} Cl_2 +$ ~~HI~~ $\Rightarrow$ ~~HCl~~ + ~~$\frac{1}{2} I_2$~~ $\Delta H = -118.115$ kJ

$\frac{1}{2}$ × ④ $\frac{1}{2} H_2 +$ ~~$\frac{1}{2} I_2$~~ $\Rightarrow$ ~~HI~~ $\Delta H = 25.9$ kJ

$\frac{1}{2} N_2 + \frac{1}{2} Cl_2 + 2H_2 \Rightarrow NH_4Cl$ $\Delta H = -315.10$kJ

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$\frac{3}{2} H_2(g) + P(s) + 2O_2(g) \Rightarrow H_3PO_4(aq)$

5. From the following information, calculate $\Delta H_{H_3PO_4(aq)}$ in kJ

a) $\Delta H_{H_2O(l)} = -285.77$ kJ
b) $\Delta H_{P_4O_{10}(s)} = -3012.48$ kJ
c) The natural form of phosphorus is P(s).
d) 13.5 g of $P_4O_{10}(s)$ is placed in exactly 1 L of water and an exothermic reaction proceeds inwhich $H_3PO_4(aq)$ is the only product. The temperature is observed to increase from 15.03 °C to 19.93°C
e) The specific heat capacity of water is 4.184 J/g°C.
f) The answer is $\Delta H_{H_3PO_4(aq)} = -308.2$ kcal

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a) ① $H_2(g) + \frac{1}{2} O_2(g) \Rightarrow H_2O(l)$ $\Delta H = -285.77$ kJ ✓

b) ② $4P(s) + 5O_2(g) \Rightarrow P_4O_{10}(s)$ $\Delta H = -3012.48$ kJ ✓

d) $P_4O_{10}(s) + 6H_2O(l) \Rightarrow 4H_3PO_4(aq)$

$Q = mc\Delta T$ ✓

$Q = 1000\,g \times 4.184\,J/g°C \times (19.93 - 15.03)°C$

$Q = 20\,501.6$ J

$Q = 20.5016$ kJ ✓

$$\frac{20.5016\,kJ}{13.5\,g\,P_4O_{10}} \times \frac{283.88\,g\,P_4O_{10}}{1\,mol\,P_4O_{10}} = 431.111\,kJ$$ ✓

$\Delta H = -Q$ ✓

$\Delta H = -431.111$ kJ

③ $P_4O_{10}(s) + 6H_2O(l) \Rightarrow 4H_3PO_4(aq)$ $\Delta H = -431.111$ kJ ✓

$\frac{1}{4} \times$ ③ $\frac{1}{4} P_4O_{10}(s) + \frac{3}{2} H_2O(l) \Rightarrow H_3PO_4(aq)$ $\Delta H = -107.778$ kJ

$\frac{1}{4} \times$ ④ $P(s) + \frac{5}{4} O_2(g) \Rightarrow \frac{1}{4} P_4O_{10}(s)$ $\Delta H = -753.48$ kJ ✓

$\frac{1}{2} \times$ ① $\frac{3}{2} H_2(g) + \frac{3}{4} O_2(g) \Rightarrow \frac{3}{2} H_2O(l)$ $\Delta H = -428.655$ kJ

$\frac{3}{2} H_2(g) + P(s) + 2O_2(g) \Rightarrow H_3PO_4$ $\Delta H = -1289.553$ kJ ✓

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