Name:_____ $\frac{\quad}{50} = \quad\%$

SCH OA1
Thermodynamics Test

1. For each of the following, decide if the situation represents an increase in potential energy or a decrease in potential energy. Label the increases in potential energy with a "+" sign and the decreases in potential energy with a "-" sign. Proceed carefully. Wrong subtracted from right.

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a) __-__ the combustion of methane gas
b) __+__ the formation of diamond from coal or graphite deep within the earths crust
c) __-__ formation of ice on a window pain through a sublimation process
d) __- or +__ formation of toluene from its constituent elements (l)
e) __+__ a reaction in which the reactants have greater forces or attraction than the products
f) __+__ evaporation of isopropyl alcohol
g) __+__ formation of an onion from all necessary raw materials
h) __+__ the conversion of ethyl alcohol to dimethyl ether
i) __-__ physical exertion
f) __+__ a tree grows in the forest

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2. For each of the following convert to a values to kJ per mol. show all conversion factors

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a) combustion of 20 mg of ethane yields 248 cal C_2H_6

$$\frac{248\,cal}{20\,mg} \times \frac{1000\,mg}{1\,g} \times \frac{30.08\,g}{1\,mol} \times \frac{4.184\,J}{1\,cal} \times \frac{1\,kJ}{1000\,J} = 1560.60\ kJ/mol$$

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b) ionization of chromium to Cr^{3+} requires approximately 19.44 meV per electron. (meV is a millielectronvolt) (1 eV = 1.6022×10^{-19} J)

$$\frac{19.44\,meV}{1\,e^-} \times \frac{1\,eV}{1000\,meV} \times \frac{1.6022\times10^{-19}\,J}{1\,eV} \times \frac{1\,kJ}{1000\,J} \times \frac{3\,e^-}{Cr^{3+}\,ion} \times \frac{6.022\times10^{23}\,Cr^{3+}\,ions}{1\,mol\,Cr^{3+}}$$

$$= 5.6263\ kJ/mol$$

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3. From the following information determine the percent by mass of a 20 kg block of ice at -30°C that can be converted to water through the combustion of 130 g of octane (C_8H_{18}).

$\Delta H_{C_8H_{18}(l)} = -250.1$ kJ

$\Delta H_{H_2O(l)} = -285.8$ kJ

$\Delta H_{CO_2(g)} = -393.5$ kJ

$c_{H_2O(l)} = 4.184$ J/g °C

$c_{H_2O(s)} = 2.010$ J/g °C

$L_{F\ H_2O} = 6.03$ kJ/mol

(8)

Note: do not use Hess' Law in your solution
Hint: start this problem using the heat summation method to determine the $\Delta H_{combustion}$ for octane.

$C_8H_{18}(l) + \frac{25}{2}O_2(g) \rightarrow 8CO_2(g) + 9H_2O(l)$ ✓

$\Delta H = [8\Delta H^\circ_{CO_2(g)} + 9\Delta H^\circ_{H_2O(l)}] - [\Delta H^\circ_{C_8H_{18}(l)} + \frac{25}{2}\Delta H^\circ_{O_2(g)}]$ ✓

$\Delta H = [8(-393.5kJ) + 9(-285.8\ kJ)] - [(-250.1kJ) + \frac{25}{2}(0)]$

$\Delta H = -5470.1$ kJ ✓

/10 $\therefore C_8H_{18}(l) + \frac{25}{2}O_2(g) \rightarrow 8CO_2(g) + 9H_2O(l) \quad \Delta H = -5470.1kJ$

$Q = -\Delta H$ ✓

$Q = 5470.1\ kJ/mol\ C_8H_{18}$

$130g\ C_8H_{18} \times \frac{1mol\ C_8H_{18}}{114.26\ g} \times \frac{5470.1kJ}{1mol} = 6223.6kJ$ ✓✓

$Q = mc\Delta T$

$Q = 20000g \times 2.010\ J/g°C \times 30°C$

$Q = 1206000$ J

$Q = 1206$ kJ ✓

heat available − heat to warm ice

6223.6 kJ $- 1206$ kJ

$= 5017.6$ kJ ✓

heat remaining to melt ice

$Q = L_F m$

$m = \frac{Q}{L_F}$

$m = \frac{5017.6\ kJ}{\frac{6.03kJ}{1mol} \times \frac{1mol}{18.02g}}$

$m = 14\,995g$

$m = 15.0kg$ ice will melt ✓

$\frac{15.0kg}{20.0kg} \times 100\% = 75\%$ by mass ✓

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4. Determine the heat of formation of urea, $CO(NH_2)_2$ using Hess' law from the information given below.

(1) $2NH_3(g) + 3H_2O(l) \Rightarrow NH_4NO_3(s) + 4H_2(g)$ $\Delta H = 583.6$ kJ

(2) $CH_2O(l) \Rightarrow CO(g) + H_2(g)$ $\Delta H = -1.9$ kJ

(3) $CH_2O(l) + 2NH_3(g) \Rightarrow CO(NH_2)_2(s) + 2H_2(g)$ $\Delta H = -133.1$ kJ

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(4), (5) & (6) heats of formation of $CO_2(g)$, $H_2O(l)$ and $NH_4NO_3(s)$ are ~~-393.5~~ -110.5 kJ, -285.8 kJ and -583.6 kJ respectively

If this question has been written correctly (i.e. Schlank didn't make a mistake, the answer should be ~~-22.5~~ -551.5 kJ)

(4) $C(s) + \frac{1}{2}O_2(g) \rightarrow CO(g)$ ✓ $\Delta H = -110.5$ kJ

(5) $H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$ ✓ $\Delta H = -285.8$ kJ

(6) $N_2(g) + 2H_2(g) + \frac{3}{2}O_2(g) \rightarrow NH_3NO_3(s)$ ✓ $\Delta H = -583.6$ kJ

Find $C(s) + \frac{1}{2}O_2(g) + N_2(g) + 2H_2(g) \rightarrow CO(NH_2)_2(s)$

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(3) ~~$CH_2O(l)$~~ + ~~$2NH_3(g)$~~ $\rightarrow CO(NH_2)_2(s)$ + ~~$2H_2(g)$~~ ✓ $\Delta H = -133.1$ kJ

rev (2) ~~$CO(g)$~~ + $H_2(g) \rightarrow$ ~~$CH_2O(l)$~~ ✓ $\Delta H = 1.9$ kJ

rev (1) ~~$NH_4NO_3(s)$~~ + ~~$\frac{1}{2}H_2(g)$~~ $\rightarrow$ ~~$2NH_3(g)$~~ + ~~$3H_2O(l)$~~ ✓ $\Delta H = -583.6$ kJ

(4) $C(s)$ ✓ + $\frac{1}{2}O_2(g)$ ✓ $\rightarrow$ ~~$CO(g)$~~ ✓ $\Delta H = -110.5$ kJ

10 (6) $N_2(g)$ ✓ + ~~$2H_2(g)$~~ + $\frac{3}{2}O_2(g) \rightarrow$ ~~$NH_3NO_3(s)$~~ ✓ $\Delta H = -583.6$ kJ

rev 3×(5) ~~$3H_2O(l)$~~ $\rightarrow$ ~~$3H_2(g)$~~ + $\frac{3}{2}O_2(g)$ ✓ $\Delta H = 857.4$ kJ

$C(s) + \frac{1}{2}O_2(g) + N_2(g) + 2H_2(g) \rightarrow CO(NH_2)_3$ ✓ $\Delta H = -551.5$ kJ

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5. The combustion of 21.9 g of ethanol C_2H_5OH is able to warm 8.000 L of water from 20 °C to 40 °C, determine the heat of formation of ethanol. ($c_{H_2O(l)}$ = 4.184 J/g °C). Do not use Hess' Law in your solution. *See question #3 for data*

$Q = mc\Delta T$

$Q = 8000g \times 4.184 J/g°C \times 20°C$

$Q = 669440 J$

(8) $Q = 669.440 kJ$

$$\frac{669.440 kJ}{21.9g\ EtOH} \times \frac{46.08g\ EtOH}{1 mol\ EtOH} = 1408.58\ kJ/mol$$

$\Delta H = -Q$

$\Delta H = -1408.58 kJ/mol$

$\therefore C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l) \quad \Delta H = -1408.58kJ$

10 $\Delta H = [2\Delta H^\circ_{CO_2(g)} + 3\Delta H^\circ_{H_2O(l)}] - [\Delta H^\circ_{C_2H_5OH(l)} + 3\Delta H^\circ_{O_2(g)}]$

$-1408.58 kJ = [2(-393.5kJ) + 3(-285.8 kJ)] - [\Delta H^\circ_{C_2H_5OH(l)} + 3(0)]$

$\Delta H^\circ_{C_2H_5OH(l)} = -235.82 kJ/mol$

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