/44 = %

Name:_______________

SCH 4U Thermodynamics Test

1. For each of the following situations, determine if the process represents an increase or a decrease in potential energy. If the process is an increase in potential energy, label it with a "+" sign. If the process is a decrease, label it with a "-" sign. Do not guess. One half mark will be deducted for each incorrect response.

+ / -	situations
–	cold water droplets form on a window
–	cellular respiration (i.e. the process in which your body converts glucose to useable energy
+	a piece of bread slowly becomes dry and hard
–	in a thermonuclear process, mass is converted to heat energy
+	photosynthesis (i.e. the process in which plants convert carbon dioxide and water to glucose and oxygen gas
+	the heat of formation of benzene
–	the heat of combustion of benzene
–	the heat of formation of ethanol
–	the formation of snow
+	a light fluffy cloud slowly dissipates leaving clear sunny skies

/10

2. Determine the heat of combustion of zinc sulphide (ZnS) given that the oxide products are zinc oxide and sulphur dioxide. Use the heat summation method for this determination (i.e. don't use Hess' Law). When you have determined the heat of combustion, write a thermochemical equation that represents this process. You must write a balanced chemical equation before you begin.

$ZnS_{(s)} + \frac{3}{2}O_{2(g)} \rightarrow ZnO_{(s)} + SO_{2(g)}$ ✓

$\Delta H = [\Delta H^\circ_{ZnO(s)} + \Delta H^\circ_{SO_2(g)}] - [\Delta H^\circ_{ZnS(s)} + \frac{3}{2}\Delta H^\circ_{O_2(g)}]$ ✓

/5

$\Delta H = [(-350.5\,kJ) + (-296.8\,kJ)] - [(-206.0\,kJ) + \frac{3}{2}(0)]$

$\Delta H = -441.3\,kJ$ ✓

$ZnS_{(s)} + \frac{3}{2}O_{2(g)} \rightarrow ZnO_{(s)} + SO_{2(g)} + 441.3\,kJ$ ✓

✓

/15

3. Determine the mass of water at 25 °C that can be converted to water at 100 °C by the combustion of 800 g of propane. At no point use Hess' Law in this determination. (For a bonus, determine what the mass of water would be if it were converted to steam at 100 °C instead of water at 100 °C)

$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$ ✓

$\Delta H = [3\Delta H^\circ_{CO_2(g)} + 4\Delta H^\circ_{H_2O(l)}] - [\Delta H^\circ_{C_3H_8(g)} + 5\Delta H^\circ_{O_2(g)}]$ ✓

$\Delta H = [3(-393.5 kJ) + 4(-285.8 kJ)] - [(-104.7 kJ + 5(0)]$

$\Delta H = -2219.0 kJ$ ✓

$Q = -\Delta H$

$Q = 2219.0 kJ/mol\ C_3H_8$ ✓

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$800 g\ C_3H_8 \times \frac{1 mol\ C_3H_8}{44.11 g\ C_3H_8} \times \frac{2219.0 kJ}{1 mol\ C_3H_8} \times \frac{1000 J}{1 kJ} = 4.024 \times 10^7 J$ ✓✓

+3 bonus

$Q = 4.024 \times 10^7 J$ ✓

$m = ?$

$c = 4.184 J/g°C$

$\Delta T = 75°C$

$m = \frac{Q}{c \Delta T}$ ✓

$m = \frac{4.024 \times 10^7 J}{4.184 J/g°C \times 75°C}$

$m = 1.282 \times 10^5 g\ H_2O$ ✓

Bonus

$Q_T = Q_1 + Q_2$

$Q_T = mc\Delta T + L_v m$ ✓

$Q_T = m(c\Delta T + L_v)$

$Q_T = m\left(4.184 J/g°C \times 75°C + \frac{40.8 kJ}{mol} \times \frac{1000 J}{1 kJ} \times \frac{1 mol}{18.02 g}\right)$

$Q_T = m(313.8 J/g + 2264.2 J/g)$

$Q_T = m(2578.0 J/g)$

since $Q_T = 4.024 \times 10^7 J$ ✓

$m = \frac{4.024 \times 10^7 J}{2578.0 J/g}$

$m = 1.561 \times 10^4 g\ H_2O$ ✓

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4. From the following data and the eventual use of Hess' Law, determine the heat of formation of calcium oxide (CaO). Note, both reactions were performed in 100 mL of 1.0 M HCl, which can be cosidered to be the same as water (i.e. specific heat capacity is 4.184 J /g°C Hummm! This looks a lot like one of your lab calculations!

Equation	Initial Temp. °C	Final Temp. °C	Masses etc.
$Ca(s) + 2HCl(aq) \Rightarrow CaCl_2(aq) + H_2(g)$	21.0	58.9	1.500 g Ca
$CaO(s) + 2HCl(aq) \Rightarrow CaCl_2(aq) + H_2O(l)$	21.0	30.2	2.000 g CaO
$H_2(g) + \frac{1}{2}O_2(g) \Rightarrow H_2O(l)$ ΔH = −285.8 kJ			

$Ca(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2(g)$ ΔH = ?

Q = ?
m = 100g
c = 4.184 J/g°C
ΔT = 58.9 − 21.0 = 37.9°C

Q = mcΔT
Q = 100g × 4.184 J/g°C × 37.9 °C
Q = 15857 J
Q = 15.857 kJ

$\frac{15.857 kJ}{1.50 g\ Ca} \times \frac{40.08 g\ Ca}{1 mol\ Ca} = 423.71$ kJ/mol

ΔH = −Q
ΔH = −431.32 kJ/mol

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∴ $Ca(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2(g)$ ΔH = −423.71 kJ

$CaO(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l)$ ΔH = ?

Q = ?
m = 100g
c = 4.184 J/g°C
ΔT = 30.2 − 21.0 = 9.2°C

Q = mcΔT
Q = 100g × 4.184 J/g°C × 9.2°C
Q = 3849 J
Q = 3.849 kJ

$\frac{3.849 kJ}{2.000 g\ CaO} \times \frac{56.01 g\ CaO}{1 mol\ CaO} = 107.80$ kJ/mol

ΔH = −Q
ΔH = −107.80 kJ/mol

∴ $CaO(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l)$ ΔH = −107.80 kJ

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① $Ca(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2(g)$ $\Delta H = -423.71\,kJ$

② $CaO(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l)$ $\Delta H = -107.80\,kJ$

③ $H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$ $\Delta H = -285.8\,kJ$

Find $Ca(s) + \frac{1}{2}O_2(g) \rightarrow CaO(s)$ $\Delta H = ?$

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① $Ca(s)$ + ~~$2HCl(aq)$~~ → ~~$CaCl_2(aq)$~~ + ~~$H_2(g)$~~ $\Delta H = -423.71\,kJ$

rev ② ~~$CaCl_2(aq)$~~ + ~~$H_2O(l)$~~ → $CaO(s)$ + ~~$2HCl(aq)$~~ $\Delta H = 107.80\,kJ$

③ ~~$H_2(g)$~~ + $\frac{1}{2}O_2(g)$ → ~~$H_2O(l)$~~ $\Delta H = -285.8\,kJ$

$Ca(s) + \frac{1}{2}O_2(g) \rightarrow CaO(s)$ $\Delta H = -601.71\,kJ$

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

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

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

③ $NO_2(g) + H_2O(l) \Rightarrow HNO_3(l) + \frac{1}{2}H_2(g)$ $\Delta H = 18.8$ kcal

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

④ $C(s) + O_2(g) \rightarrow CO_2(g)$ ✓ $\Delta H = -393.5$ kJ or -94.05 kcal ✓

⑤ $H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$ $\Delta H = -285.8$ kJ or -68.31 kcal

⑥ $\frac{1}{2}N_2(g) + O_2(g) \rightarrow NO_2(g)$ $\Delta H = +33.2$ kJ or $+7.93$ kcal

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Find $7C(s) + \frac{7}{2}H_2(g) + O_2(g) + \frac{1}{2}N_2(g) \rightarrow C_7H_7O_2N(l)$ ✓

/ ① $C_7H_8(l) + HNO_3(l) \rightarrow C_7H_7O_2N(l) + H_2O(l)$ $\Delta H = -47.25$ kcal

rev ② $7CO_2(g) + 4H_2O(l) \rightarrow C_7H_8(l) + 9O_2(g)$ $\Delta H = 943.1$ kcal

/ ③ $NO_2(g) + H_2O(l) \rightarrow HNO_3(l) + \frac{1}{2}H_2(g)$ $\Delta H = 18.8$ kcal

7× ④ $7C(s) + 7O_2(g) \rightarrow 7CO_2(g)$ ✓ $\Delta H = -658.35$ kcal

4× ⑤ $4H_2(g) + 2O_2(g) \rightarrow 4H_2O(l)$ $\Delta H = -273.24$ kcal

⑥ $\frac{1}{2}N_2(g) + O_2(g) \rightarrow NO_2(g)$ $\Delta H = 7.93$ kcal

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$7C(s) + \frac{7}{2}H_2(g) + O_2(g) + \frac{1}{2}N_2(g) \rightarrow C_7H_7O_2N(l)$ $\Delta H = -9.01$ kcal ✓

✓

8

8