DO NOT SUBMIT

1) Indicate if the following reactions are endo or exothermic.

$CH_4\,(g) + 2O_2\,(g) \longrightarrow CO_2\,(g) + 2H_2O\,(g)$ $\Delta H = -890.3$ kJ/mol

exo

$2HgO\,(s) \longrightarrow 2Hg\,(s) + O_2\,(g)$ $\Delta H = +181.66$ kJ/mol

endo

2) Given equation (a) below, calculate the ΔH for equation (b). (Ans: -26.48 kJ/mol)

(a) $H_2\,(g) + I_2\,(s) \longrightarrow 2HI\,(g)$ $\Delta H = +52.96$ kJ/mol

(b) $HI\,(g) \longrightarrow \frac{1}{2} H_2\,(g) + \frac{1}{2} I_2\,(s)$

ΔH rev x ÷2

3) Given equation (a) below, calculate the ΔH for equation (b). (Ans: +142.7 kJ/mol)

(a) $3O_2\,(g) \longrightarrow 2O_3\,(g)$ $\Delta H = +285.4$ kJ/mol

(b) $3/2\ O_2\,(g) \longrightarrow O_3\,(g)$

ΔH ÷2

4) Write the thermochemical equation that expresses that at 0 °C ice melts by absorbing 334 J of heat per gram. (Ans: +6.02 kJ)

$H_2O_{(s)} \longrightarrow H_2O_{(l)}$ $\Delta H = 334\,J/g$

$$334\frac{J}{g} \times \frac{18g}{1mol} \times \frac{1\,kJ}{1000J} = \boxed{6.02\,kJ}$$

5) The complete combustion of liquid octane, C_8H_{18}, produces carbon dioxide and water at 25.0 °C and at constant pressure, it gives 47.9 kJ of heat per gram of octane. Write the thermochemical equation to show this information. (Ans: -1.09×10^4 kJ)

$C_8H_{18} = 114.2g/mol$

$$\frac{-47.9\,kJ\ C_8H_{18}}{1g} \times \frac{114.2g\ C_8H_{18}}{1mol} = -5.47\times10^3\,kJ/mol$$

x2.

$(C_8H_{18} + 25/2\ O_2 \longrightarrow 8CO_2 + 9H_2O) \times 2$

$2C_8H_{18} + 25O_2 \longrightarrow 16CO_2 + 18H_2O$ $\Delta H = \boxed{-1.09\times10^4\,kJ}$

6) Answer the following two questions using the equation given below.

$H_2(g) + Cl_2(g) \longrightarrow 2HCl(g) \quad \Delta H = -184.6$ kJ

a) What is the enthalpy change associated with the formation of 5.67 mol HCl gas in the following reaction? (Ans: -523 kJ)

$5.67\text{ mol HCl} \times \frac{-184.6\text{ kJ}}{\text{mol}} = \boxed{-523\text{ kJ}}$

b) What is the enthalpy change when 12.8 g of H_2 gas reacts with excess Cl_2 gas to form HCl? (Ans: -1.17×10^3 kJ)

$12.8\text{ g } H_2 \times \frac{1\text{ mol } H_2}{2.016\text{ g } H_2} \times \frac{-184.6\text{ kJ}}{1\text{ mol}} = \boxed{-1.17 \times 10^3\text{ kJ}}$

7) The reaction of sodium peroxide and water is a source of oxygen gas.

$2Na_2O_2(s) + 2H_2O(l) \longrightarrow 4\,NaOH(aq) + O_2(g) \quad \Delta H = -287$ kJ

How many kilojoules of heat are evolved in a reaction of 226 g Na_2O_2 with 98.5 g H_2O? (Ans: -416 kJ)

$226\text{ g } Na_2O_2 \times \frac{1\text{ mol } Na_2O_2}{77.98\text{ g}} \times \frac{1\text{ mol } O_2}{2\text{ mol } Na_2O_2} = 1.45\text{ mol } O_2$ $\boxed{LR}$

$98.5\text{ g } H_2 \times \frac{1\text{ mol } H_2O}{18\text{ g}} \times \frac{1\text{ mol } O_2}{2\text{ mol } H_2O} = 2.73\text{ mol } O_2$

$\frac{-287\text{ kJ}}{2\text{ mol } Na_2O_2} \times 226\text{ g } Na_2O_2 \times \frac{1\text{ mol } Na_2O_2}{77.98\text{ g}} = \boxed{-416.\text{ kJ}}$

Show all the work for the calculations and give the answers in the correct significant figures.

8) Calculate the heat capacity of a piece of iron if a temperature rises from 18 to 69 °C requires 672 J of heat. (Ans: 13 J/°C)

$\Delta T = 69 - 18 = 51°C$

$q = C\Delta T$

$C = \frac{q}{\Delta T} = \frac{672}{51} = \boxed{13\ J/°C}$

9) How much heat in kJ is required to raise the temperature of
   a) A 320.0 g of water from 15.0 to 96.0 °C? (sp heat water = 4.18 J/g °C) (Ans: 108 kJ)

$q = ms\Delta T = 320g \times 4.18\ J/g°C \times (96 - 15)°C$

$= \boxed{108\ kJ}$

   b) And 74.3 g of ethanol from -36.4 to 44.5 °C? (sp heat ethanol = 2.46 J/g °C) (Ans: 14.8 kJ)

$q = 74.3 \times 2.46 J/g°C \times (44.5 - (-36.4))°C$

$= \boxed{14.8\ kJ}$

10) A 638 g block of lead initially at 27.0 °C absorbs 2044 J of heat. What is the final temperature of the lead block? (sp heat lead = 0.128 J/g °C) (Ans: 52.0 °C)

$\Delta T = \frac{q}{ms} = \frac{2044}{638 \times 0.128 J/g°C} = 25°C$

$25°C = T_f - 27°C$

$\boxed{T_f = 52°C}$

11)A 9.13 g sample of vanadium is heated to 99.10 °C and is then dropped into 20.0 g water in a calorimeter. The water temperature rises from 20.51 °C to 24.46 °C. Calculate the specific heat of vanadium. (Ans: -0.485 J/g °C)

$-q_V = +q_{H_2O}$ $\boxed{OR}$ $q_{H_2O} + q_V = 0$

$[9.13g \times (s) \times (24.46 - 99.10)] + \{20g \times 4.18 J/g°C \times (24.46 - 20.51)\}$

$-681.46(s) + 330.2 = 0$

$s = \frac{330.2}{681.46} = \boxed{0.485\ J/g°C}$

12)What is the final temperature of water when 20.2 g of water at 95.4 °C is mixed with 50.5 g water at 26.7 °C? (Ans: 46.3 °C)

$-q_{H_2O} = +q_{H_2O}$ $\boxed{OR}$ $\underset{hot}{q_{H_2O}} + \underset{cold}{q_{H_2O}} = 0$

$\{20.2g \times 4.184 \times (T_f - 95.4)] + [50.5g \times 4.184 \times (T_f - 26.7)]$

$(84.5168T_f - 8062.9) + (211.29T_f - 5641.5)$

$295.81T_f - 13704.4 = 0$

$13704.4 / 295.81 = T_f = \boxed{46.3°C}$

13)A 500.0 mL sample of 0.500 M NaOH at 20.00 °C is mixed with an equal volume of 0.500 M HCl at the same temperature in a foam cup calorimeter. The temperature rises to 23.21 °C. What is the ΔH of the reaction? (Ans: -53.5 kJ/mol)

total vol = 500 + 500 = 1000 mL
$\equiv$ 1000 g

a) $q_{cal} = ms\Delta T = 1000g \times 4.18 J/g°C \times (23.21 - 20)°C = 13.42 kJ$

$q_{rxn} = -q_{cal} = -13.42\ kJ$

b) Calc. mols. $0.5L \times \frac{0.5 mol}{L} = 0.25 mol\ NaOH \times \frac{1 mol\ H_2O}{1 mol\ NaOH} = 0.25\ mol$

c) molar $\Delta H = -13.42\ kJ / 0.25\ mol = \boxed{-53.7\ kJ}$

~~1~~4)A 250.0 mL sample of 0.250 M NaOH at 21.00 °C is mixed with an equal volume of 0.500 M H_2SO_4 at the same temperature in a foam cup calorimeter. The temperature rises to 26.52 °C. What is the ΔH of the reaction? (Ans: 92.4 kJ/mol)

$2NaOH + H_2SO_4 \longrightarrow Na_2SO_4 + H_2O$

total vol = 250 + 250 = 500 mL ≡ 500 g

a) $q_{cal} = ms\Delta T$
$= 500 \times 4.184 \times (\underbrace{26.52 - 21}_{5.52})$
$= 1.155 \times 10^4$ J ≅ 11.5 kJ $q_{rxn} = -q_{cal} = -11.5$ kJ

b) mol NaOH $0.25L \times 0.25M = 0.0625$ mol – LR
H_2SO_4 $0.25L \times 0.5M = 0.125$ mol.

c) $\Delta H = 11.5\,kJ / 0.0625\,mol = \boxed{184\,kJ/mol}$.

15)A 1.50 g sample of $NH_4NO_3(s)$ is added to 35.0 g of water in a foam cup calorimeter and stirred until dissolved. The temperature of the solution drops from 22.7 to 19.4 °C. What is the enthalpy the NH_4NO_3 solution? (Ans: +25.8 kJ/mol)

a) $q_{cal} = ms\Delta T = 35g\,H_2O \times 4.184 J/g°C \times (19.4 - 22.7)°C$
$= -483 J$

$q_{rxn} = -q_{cal} = +483 J$ (MW NH_4NO_3 = 80.03 g/mol)

b) $\frac{483 J}{1.5g\,NH_4NO_3} \times \frac{80.05g\,NH_4NO_3}{1\,mol} = \boxed{26\,kJ/mol}$.

16)Express the equation below as a thermochemical equation when 30.12 g of ethane is combusted in oxygen in a bomb calorimeter. The temperature in the calorimeter changes from 25.6 °C to 40.0 °C. The heat capacity of the calorimeter is 2.33 kJ/°C.

(Ans: -33.4 kJ/mol)

$2C_2H_6(g) + 7O_2(g) \longrightarrow 4H_2O(l) + 6CO_2(g)$

$-q = C\Delta T = 2.33\,kJ/°C \times (\underbrace{40.0 - 25.6}_{14.4°C})°C$

$= -33.552$ kJ

$30.12g\,C_2H_6 \times \frac{1\,mol}{30g} = 1.004\,mol$.

$33.552\,kJ / 1.004\,mol = \boxed{-33.4\,kJ}$.

17)Use the equations a and b to calculate the enthalpy change for the equation given below.

$2C\ (graphite) + O_2(g) \longrightarrow 2CO(g)$ ΔH = ? (Ans: -221.0 kJ)

Given:

a) $C(graphite) + O_2\ (g) \longrightarrow CO_2\ (g)$ ΔH = -393.5 kJ ×2

b) $2CO\ (g) + O_2\ (g) \longrightarrow 2CO_2\ (g)$ ΔH = -566.0 kJ rev.

$2C + 2O_2 \longrightarrow 2CO_2$ (-393.5)×2

$2CO_2 \longrightarrow 2CO + O_2$ +566

+ $\boxed{-221.0\ kJ}$

18)Use the equations a and b to calculate the enthalpy change for the equation given below.

$2NO_2\ (g) \longrightarrow N_2O_4\ (g)$ ΔH = ? (Ans: -24.0 kJ)

Given:

a) $N_2\ (g) + 2O_2\ (g) \longrightarrow N_2O_4\ (g)$ ΔH = +9.2 KJ — as is

b) $N_2\ (g) + 2O_2\ (g) \longrightarrow 2NO_2\ (g)$ ΔH = +33.2 KJ rev.

$N_2 + 2O_2 \longrightarrow N_2O_4$ +9.2

$2NO_2 \longrightarrow N_2 + 2O_2$ -33.2

+ $\boxed{-24.0\ kJ}$

19)Use the equations given to calculate the enthalpy change for the equation given below. Show the process to get to your answer. (Ans: 219 kJ)

$BrCl\ (g) \longrightarrow Br\ (g) + Cl\ (g)$ ΔH = ?

Given:

a) $Br_2\ (l) \longrightarrow Br_2\ (g)$ ΔH = + 30.9 kJ ½

b) $Br_2\ (g) \longrightarrow 2Br\ (g)$ ΔH = +192.9 kJ ½

c) $Cl_2\ (g) \longrightarrow 2Cl\ (g)$ ΔH = +243.4 kJ ½

d) $Br_2\ (l) + Cl_2\ (g) \longrightarrow 2BrCl\ (g)$ ΔH = + 29.2 kJ ½ & rev.

$\frac{1}{2}Br_2(l) \longrightarrow \frac{1}{2}Br_2(g)$ +15.455

$\frac{1}{2}Br_2(g) \longrightarrow Br(g)$ +96.45

$\frac{1}{2}Cl_2(g) \longrightarrow Cl_2(g)$ + 121.7

$BrCl \longrightarrow \frac{1}{2}Br(l) + \frac{1}{2}Cl_2(g)$ (+) - 14.6.

$\boxed{219\ kJ}$

*20) Use the standard enthalpies of formation given below to calculate the standard enthalpy change for the following two reactions.

(ΔH_f° in kJ/mol: Al_2O_3 = -1676, $Al(OH)_3$ = -1276, H_2O = -285.8; C_2N_2 = 308.9, CO_2 = -393.5)

a) Al_2O_3 (s) + $3H_2O$(l) $\longrightarrow$ $2Al(OH)_3$(s) (Ans: ~~+7698 kJ~~) 18.6 kJ

$$\underbrace{-1676 + (-285.8) \times 3}_{-2533.4} \quad \underbrace{(-1276) \times 2}_{-2552}$$

$$\Delta H = \text{prod} - \text{react} = -2552 - (-2533.4) = \boxed{-18.6\ kJ}$$

b) C_2N_2 (g) + $2O_2$ (g) $\longrightarrow$ $2CO_2$ (g) + N_2 (g) (Ans: -1095.9 kJ)

$$\underbrace{(308.9) + 2(0)}_{308.9} \quad \underbrace{3(-393.5) + 0}_{-787}$$

$$\Delta H = \text{prod} - \text{react} = -787 - (308.9)$$
$$= \boxed{-1095.9\ kJ}$$