

Thermochemistry

Date Planned : __ / __ / __	Daily Tutorial Sheet	Expected Duration : 90 Min
Actual Date of Attempt : __ / __ / __	Level-0	Exact Duration : _____

Very Short Answer Type (1 Mark)

- The heat of combustion of benzene in a bomb calorimeter (i.e., constant volume) was found to be $3263.9 \text{ kJ mol}^{-1}$ at 25°C . Calculate the heat of combustion of benzene at constant pressure.
- The molar heat of formation of $\text{NH}_4\text{NO}_3(\text{s})$ is -367.54 kJ and those of $\text{N}_2\text{O}(\text{g})$ and $\text{H}_2\text{O}(\text{l})$ are $+81.46$ and -285.78 kJ respectively at 25°C and 1.0 atmospheric pressure. Calculate ΔH and ΔU for the reaction.
- 1 g of graphite is burnt in a bomb calorimeter in excess of oxygen at 298 K and 1 atmospheric pressure according to the equation $\text{C}(\text{graphite}) + \text{O}_2(\text{g}) \longrightarrow \text{CO}_2(\text{g})$. During the reaction, temperature rises from 298 K to 299 K. If the heat capacity of the bomb calorimeter is 20.7 kJ/K , what is the enthalpy change for the above reaction at 298 K and 1 atm ?
- Calculate the enthalpy of hydration of anhydrous copper sulphate (CuSO_4) into hydrated copper sulphate ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$). Given that the enthalpies of solution of anhydrous copper sulphate and hydrated copper sulphate are -66.5 and $+11.7 \text{ kJ mol}^{-1}$ respectively.
- Calculate the standard enthalpy of formation of SO_3 at 298 K using the following reactions and enthalpies.
 $\text{S}_8(\text{s}) + 8\text{O}_2(\text{g}) \longrightarrow 8\text{SO}_2(\text{g}), \Delta H^\circ = -2775 \text{ kJ mol}^{-1};$
 $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \longrightarrow 2\text{SO}_3(\text{g}), \Delta H^\circ = -198 \text{ kJ mol}^{-1}$
- From the following data at 25°C , calculate the bond energy of O – H bond:
(i) $\text{H}_2(\text{g}) \longrightarrow 2\text{H}(\text{g}), \Delta H_1 = 104.2 \text{ kcal}$ **(ii)** $\text{O}_2(\text{g}) \longrightarrow 2\text{O}(\text{g}), \Delta H_2 = 118.4 \text{ kcal}$
(iii) $\text{H}_2(\text{g}) + \frac{1}{2}\text{O}_2(\text{g}) \longrightarrow \text{H}_2\text{O}(\text{g}), \Delta H_3 = -57.8 \text{ kcal}$

Short Answer Type-I (2 Marks)

- A 1.250 g sample of Octane (C_8H_{18}) is burned in excess of oxygen in a bomb calorimeter. The temperature of the calorimeter rises from 294.05 K to 300.78 K. If heat capacity of the calorimeter is 8.93 kJ/K , find the heat transferred to the calorimeter. Also calculate the enthalpy combustion of the sample of octane.
- 0.16 g of methane was subjected to combustion at 27°C in a bomb calorimeter system. The temperature of the calorimeter system (including water) was found to rise by 0.5°C . Calculate the heat of combustion of methane at (i) constant volume, and (ii) constant pressure. The thermal capacity of the calorimeter system is 17.7 kJ K^{-1} ($R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1}$)

9. Calculate enthalpy of formation of methane (CH_4) from the following data :
- (i) $\text{C(s)} + \text{O}_2(\text{g}) \longrightarrow \text{CO}_2(\text{g}), \Delta_f H^\circ = -393.5 \text{ kJ mol}^{-1}$
- (ii) $\text{H}_2(\text{g}) + \frac{1}{2}\text{O}_2(\text{g}) \longrightarrow \text{H}_2\text{O}(\ell), \Delta_f H^\circ = -285.8 \text{ kJ mol}^{-1}$
- (iii) $\text{CH}_4(\text{g}) + 2\text{O}_2(\text{g}) \longrightarrow \text{CO}_2(\text{g}) + 2\text{H}_2\text{O}(\ell), \Delta_f H^\circ = -890.3 \text{ kJ mol}^{-1}$
10. Ethylene on combustion gives carbon dioxide and water. Its enthalpy of combustion is 1410.0 kJ / mol . If the enthalpy of formation of CO_2 and H_2O are -393.3 kJ and -286.2 kJ respectively, calculate the enthalpy of formation of ethylene.
11. Calculate the enthalpy of formation of sucrose ($\text{C}_{12}\text{H}_{22}\text{O}_{11}$) from the following data:
- (i) $\text{C}_{12}\text{H}_{22}\text{O}_{11} + 12\text{O}_2 \longrightarrow 12\text{CO}_2 + 11\text{H}_2\text{O}, \Delta H = -5200.7 \text{ kJ mol}^{-1}$
- (ii) $\text{C} + \text{O}_2 \longrightarrow \text{CO}_2, \Delta H = -394.5 \text{ kJ mol}^{-1}$
- (iii) $\text{H}_2 + \frac{1}{2}\text{O}_2 \longrightarrow \text{H}_2\text{O}, \Delta H = -285.8 \text{ kJ mol}^{-1}$
12. Compare quantity of heat produced by the combustion of 1.0 g glucose ($\text{C}_6\text{H}_{12}\text{O}_6$) with that produced by 1.0 g sucrose ($\text{C}_{12}\text{H}_{22}\text{O}_{11}$). Given that the standard heats of formation of CO_2 , H_2O glucose and sucrose are -393.5 , -285.9 , -1260 and $-2221 \text{ kJ mol}^{-1}$ respectively.
13. (a) Is the bond energy of all the four C – H bonds in CH_4 molecule equal? If not then why? How is the C – H bond energy then reported?
- (b) Same mass of diamond and graphite (both being carbon) are burnt in oxygen. Will the heat produced be same or different? Why? Give reasons for the following:

Short Answer Type-II (3 Marks)

14. Calculate the bond energy of C – H bond, given that the heat of formation of CH_4 , heat of sublimation of carbon and heat of dissociation of H_2 are $-74.8 + 719.6$ and 435 kJ mol^{-1} respectively.
15. Use the following data to calculate $\Delta_{\text{lattice}} H^\circ$ for NaBr. $\Delta_{\text{sub}} H^\circ$ for sodium metal = $108.4 \text{ kJ mol}^{-1}$, ionization enthalpy of sodium = 496 kJ mol^{-1} , electron gain enthalpy of bromine = -325 kJ mol^{-1} , bond dissociation enthalpy of bromine = 192 kJ mol^{-1} , $\Delta_f H^\circ$ for NaBr(s) = $-360.1 \text{ kJ mol}^{-1}$.
16. Show that the reaction $\text{CO(g)} + \frac{1}{2}\text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g})$ at 300 K is spontaneous and exothermic, when the standard entropy change is $-0.094 \text{ kJ mol}^{-1} \text{ K}^{-1}$. The standard Gibbs energies of formation for CO_2 and CO are -394.4 and $-137.2 \text{ kJ mol}^{-1}$, respectively.
17. The heat of neutralization of (i) $\text{CHCl}_2 - \text{COOH}$ by NaOH is 12830 cal , (ii) HCl by NaOH is 13680 cal and (iii) NH_4OH by HCl is 12270 cal . What is the heat of neutralization of dichloro acetic acid by NH_4OH ? Calculate the heats of ionization of dichloro acetic acid and NH_4OH .

18. A natural gas may be assumed to be a mixture of CH_4 and C_2H_6 only. On complete combustion of 10 L of the gas at STP, the heat evolved was 474.6 kJ. Assuming $\Delta H_{\text{c}}(\text{CH}_4) = -894 \text{ kJ/mol}$ and $\Delta H_{\text{c}}(\text{C}_2\text{H}_6) = -1560 \text{ kJ/mole}$. Calculate the % by volume of each gas in the mixture.
19. The enthalpy of evaporation of water at 373 K is $40.67 \text{ kJ mol}^{-1}$. What will be the enthalpy of evaporation at 353 K and 393 K if average molar heats at constant pressure in this range for water in liquid and vapour states are 75.312 and $33.89 \text{ JK}^{-1} \text{ mol}^{-1}$ respectively?

Long Answer Type (5 Marks)

20. Classify the following processes as exothermic or endothermic.
- (A) Burning of match stick
 (B) Melting of ice
 (C) Molten metal solidifies
 (D) Reaction between Na and H_2O
 (E) Rubbing alcohol evaporates
21. Using the data (all value in kilocalories per mole at 25°C) given below. Calculate the bond energy of C - C and C - H bonds.

$$\Delta H^\circ_{\text{C (Ethane)}} = -372$$

$$\Delta H^\circ_{\text{C (Propane)}} = -530$$

$$\Delta H_{\text{C (Graphite) - C(g)}} = 172$$

$$\text{Bond energy of H - H} = 104$$

$$\Delta H^\circ_{\text{f H}_2\text{O(l)}} = -68$$

$$\Delta H^\circ_{\text{f CO}_2(\text{g})} = -94$$

22. Using the data given below (all values are in kcal mol^{-1} at 25°C), calculate the bond energies of C—C and C—H bonds.

$$\Delta H^\circ \text{ (combustion) of ethane} = -372.0$$

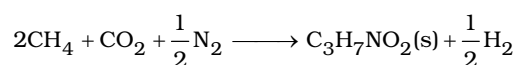
$$\Delta H^\circ \text{ (combustion) of propane} = -530.0$$

$$\Delta H^\circ \text{ for C(s)} \longrightarrow \text{C(g)} = 172.0$$

$$\text{Bond energy of H—H bond} = 104.0$$

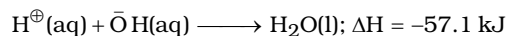
$$\Delta_f H^\circ \text{ of H}_2\text{O} = 68.0; \Delta_f H^\circ \text{ of CO}_2(\text{g}) = -94.0$$

23. Standard enthalpy of formation of $\text{C}_3\text{H}_7\text{NO}_2(\text{s})$, $\text{CO}_2(\text{g})$ and $\text{H}_2\text{O(l)}$ are 133.57, -94.05, and -68.32 kcal mol^{-1} respectively. Standard enthalpy of combustion of CH_4 at 25°C is $-212.8 \text{ kcal mol}^{-1}$. Calculate ΔH° for the reaction:



Calculate ΔU for combustion of $\text{C}_3\text{H}_7\text{NO}_2(\text{s})$.

24. Whenever an acid is neutralized by a base, the net reaction is



Calculate the heat evolved for the following experiments?

- (a) 0.50 mol of HCl solution is neutralized by 0.50 mol of NaOH solution.
 - (b) 0.50 mol of HNO_3 solution is mixed with 0.30 mol of KOH solution
 - (c) 100 mL of 0.2 M HCl is mixed with 100 mL of 0.3 M NaOH solution
 - (d) 400 mL of 0.2 M H_2SO_4 is mixed with 600 mL of 0.1 M KOH solution
25. The standard entropy change for reaction $\text{CO}(\text{g}) + \frac{1}{2}(\text{O}_2) \longrightarrow \text{CO}_2(\text{g})$ at 300 K is $-0.094 \text{ kJ mol}^{-1} \text{ K}^{-1}$. The standard Gibbs free energies of formation of CO_2 and CO are -394.4 and $-137.2 \text{ kJ mol}^{-1}$ respectively. What is effect of temperature on spontaneity of reaction ?