Miscellaneous Exercise Question Bank

1.(A) $TV^{\gamma-1} = k$

$\therefore \quad T_2 = T_1\left(\dfrac{V_1}{V_2}\right)^{\gamma-1}$

$\Rightarrow$ Since $\dfrac{V_1}{V_2} > 1 \quad \Rightarrow \quad T_2$ is greater for higher value of γ

$\therefore \quad T_2$ is greater for monoatomic gas X.

2.(A) $PV^{\gamma} = k$

$\log P + \gamma \log V = \log k$

$\Rightarrow \quad \log P = -\gamma \log V + \log k$

$\therefore$ Slope $= -\gamma$

Since graph C has lowest slope

$\therefore$ Graph C is for highest value of γ i.e. for monoatomic gas

3.(BD) For a process to be spontaneous $(\partial G)_{T,P} < 0, (\partial E)_{S,V} < 0$

4.(C) Absolute value of entropy can be known

Absolute value of internal energy cannot be known and ΔG_f° can be known

5.(BD) According to second law, entropy of universe is continuously increasing and all spontaneous process are thermodynamically irreversible

6.(ABCD)

$G = H - TS$

$\Delta E = q + w$

$\Delta H = \Delta E + \Delta n_g RT$

$H = E + PV$

7.(C) In stretching of rubber band entropy decreases but in all other cases entropy increases.

8.(ACD) $|w_{rev}| > |w_{irr}|$ (for isothermal expansion)

$\Delta G^{\circ} \neq 0$ (at equilibrium)

$\Delta G = \Delta S = 0$ (at equilibrium)

$\Delta H < 0$ for exothermic reaction

9.(D) $\Delta G < 0$ for spontaneous process

$\Delta G = \Delta H - T\Delta S$

10.(B) Both are correct but not correct explanation

11.(A) For cyclic process, $\Delta G = \Delta H = \Delta S = 0$ because all are state functions

12.(B) Both are correct but not correct explanation

13.(B) $\Delta G = \Delta H - T\Delta S$

14.(C) $\Delta G = \Delta H - T\Delta S$

15. **(A→ p, q, r, s, t ; B→ p, q, t; C→ p, q, r, s, t; D→r, s)**

(A) u_{rms} increase with increase in temperature

If a gas does adiabatic work

⇒ $q = 0,\ w = -\text{ve}$

∴ $\Delta U = -\text{ve}$ ⇒ Temperature is decreasing

⇒ u_{rms} decreases when gas undergoes dimerisation as molecular mass increases

⇒ u_{rms} increases when gas undergoes dissociation

(B) KE increase as T increase

(C) PV increase with increase in number of moles and increase in temperature

(D) $\frac{1}{T_c}$ increases when attraction decreases

16. **(A→ s; B→ r; C→ p, t; D→ q)**

(A)	Clausius - Clapeyron equation	$\ln\frac{P_2}{P_1} = \frac{\Delta H_v}{R}\left[\frac{1}{T_1} - \frac{1}{T_2}\right]$
(B)	Kirchhoff's equation	$\left[\frac{\partial(\Delta G)}{\partial T}\right] = \Delta C_p$
(C)	Gibb's Helmholtz equation	$\Delta G = \Delta H + T\left[\frac{\partial(\Delta G)}{\partial T}\right]_P$; $\Delta G = \Delta U + T\left(\frac{\partial(\Delta G)}{\partial t}\right)_V$
(D)	Van't Hoff Isochore	$\frac{d\ell nK_P}{dT} = \frac{\Delta H^\circ}{RT^2}$

17. **(A→ q; B→ r; C→ p; D→ s)**

$\Delta G^\ominus = -RT\,\ell nK$

$\Delta H = \Delta U + P\Delta V$

$\Delta S = nR\,\ell n\frac{V_2}{V_1}$

$\Delta G = -nFE$

18.(A) Since the given process is in equilibrium i.e. $\Delta G = 0$

$\Delta G = \Delta H - T\,\Delta S$

or $0 = \Delta H - T\Delta S$ or $\Delta H = T\Delta S$

or $\Delta S = \frac{\Delta H}{T} = \frac{6}{273}\times 10^3\ \text{JK}^{-1}\ \text{mole}^{-1} = 21.98\ \text{JK}^{-1}\text{mole}^{-1}$

Hence, **(A)** is the correct answer.

19.(A) ΔG is +ve if ΔH is +ve and ΔS is –ve. Thus, reaction is non-spontaneous.

Hence, **(A)** is the correct answer.

20.(C) Energy available for muscular work $= \frac{2880\times 25}{100} = 720$ kJ / mol

∴ Energy available for muscular work for 120 g glucose $= \frac{720\times 120}{180} = 480$ kJ

∵ 100 kJ is used in 1 km distance

∴ 480 kJ is used in 4.8 km distance.

21.(D)
- For reversible adiabatic process ΔS_{Total} Total as well as ΔS_{sys} is equal to zero.
- The reversible work will depend on the path, exception being some particular cases, for example the adiabatic case, is which q = 0, so that $\Delta U = -W$ and W is therefore path independent.
- Heat capacity is extensive property

22.(A) $\Delta G = \Delta H - T\Delta S$

23.(C) $(\Delta S)_{sys} = nC_{V,m}\,\ell n\dfrac{T_2}{T_1} + nR\,\ell n\dfrac{V_2}{V_1}$

For isothermal free expansion; $T_2 = T_1$

$\Rightarrow \quad (\Delta S)_{sys} = nR\,\ell n\dfrac{V_2}{V_1} = 1\times R\,\ell n\dfrac{3V}{V} = R\,\ell n3$

24.(C) $W_{BDA} = 10J = W_{BD} + W_{DA} = W_{DA}$

$q_{BDA} = -60\,J$

$\Rightarrow \quad (\Delta U)_{B\to A} = 10 - 60 = -50\,J = U_A - U_B \quad \Rightarrow \quad U_A - U_B = -50$

$U_B - U_C = 30$

$\therefore \quad U_C - U_A = 20 = q_{AC}\,(W = 0)$

$\Rightarrow \quad W_{ACB} = -20 = W_{CB}$

$\Delta U_{CB} = 30\,J \quad \therefore \quad q = 30 + 20 = 50\,J$

25.(C) $W = -P_{ext}\Delta V = -1.25\times 32 = -40\,\text{lt - bar} = -4000\,J = -4\,kJ$

$\Delta U = -51\,kJ$

$\therefore \quad q = -47\,kJ$

26.(A) $W_{max} = W_{rev} = -nRT\,\ell n\dfrac{V_2}{V_1} = -1\times 8.314\times 310\,\ell n\dfrac{25}{15} = 1316\,J$

27.(A)
(A) Randomness decreases
(B) Randomness increases
(C) Randomness increases as gaseous moles increasing
(D) Randomness increases as gaseous moles increasing

28.(B) HA is more acidic as heat released is more.
So pH of HB is higher than that of HA.

29.(D) For irreversible process, only initial and final states are defined

30.(B) $\Delta H = \Delta U + \Delta(PV)$

31.(B) $\Delta G^\circ = -RT\,\ell n K_p$

Now $\quad \Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$

32.(C) Amount of heat released is same as number of moles are same in both cases

$\Rightarrow \quad q = ms\Delta T \quad \Rightarrow \quad 2\times s\times 10 = 3\times s\times \Delta T$

$\Rightarrow \quad \Delta T = \dfrac{20}{3} = 6.67^\circ C$

33.(C) $\Delta S = \frac{\Delta H}{T} = \frac{-6000}{273} = -21.98\,J/mol\text{-}K$

34.(A)

$$\begin{array}{lll} & N_2O_4 \rightleftharpoons & 2\,NO_2 \\ t = 0 & 1\,\text{mole} & \\ t & (1-x)\,\text{mole} & 2x\,\text{mole} \end{array}$$

$$\Rightarrow \quad (M)_{avg} = 2\times\frac{230}{6} = \frac{92}{1+x} \quad \Rightarrow \quad 230 + 230x = 276 \quad \Rightarrow \quad x = \frac{46}{230}$$

$$\therefore \quad K_p = \left[\frac{2\times\frac{46}{230}\Big/1+\frac{46}{230}}{1-\frac{46}{230}\Big/1+\frac{46}{230}}\right]; \qquad \text{Now} \quad \Delta G^\circ = -RT\,\ell n\,K_p$$

35.(C) Entropy is a state function

36.(A) Heat released by iron = Heat gained by water

$$\Rightarrow \quad 10\times 0.45\times(100-T) = 25\times 4.2\times(T-27^\circ) \quad \Rightarrow \quad T = 30^\circ C$$

37.(A) $\Delta U = W = -75\,cal = nC_{V,m}\,\Delta T$

$$\Rightarrow \quad -75 = \frac{0.1\times 3\times 2}{2}\times\Delta T \quad \Rightarrow \quad \Delta T = -250$$

$$\therefore \quad T_2 = 250\,K$$

38.(C) $c = \frac{R}{\gamma-1} + \frac{R}{1-n} \qquad \left[n = \frac{1}{2} \text{ for this polytropic process}\right]$

$$c = \frac{R}{\frac{5}{3}-1} + 2R = \frac{3R}{2} + 2R = \frac{7R}{2}$$

39.(C) $\Delta S = nC_{p,m}\,\ell n\frac{T_2}{T_1} = 2.5\times 18\times 4.2\,\ell n\frac{360}{300} = 34.02\,J/K$

40.(B) $\Delta S^\circ = 2\,S^\circ_{Fe} + 3\,S^\circ_{H_2O} - S^\circ_{Fe_2O_3} - 3\,S^\circ_{H_2}$

41.(C) $\Delta G = \Delta H - T\Delta S$

For isothermal expansion of ideal gas, $\Delta H = 0$

$$\therefore \quad \Delta G = -T\Delta S$$

42.(C) $\Delta S = \frac{\Delta H}{T} = \frac{40.85\times 0.2}{373} = 0.0219\,kJ/K = 21.9\,J/K$

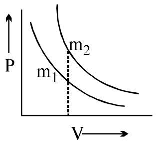
43.(C) $\Delta G = nRT\,\ell n\frac{P_2}{P_1} = nRT\,\ell n\frac{V_1}{V_2} = 1\times 8.314\times 300\,\ell n\frac{1}{2} = -1.728\,kJ/mol\,K$

44.(B) I, II and V are correct statements

45.(A) $\Delta S = 0 = nC_{P,m}\,\ell n\frac{T_2}{T_1} + nR\,\ell n\frac{P_1}{P_2}$

$$\Rightarrow \quad \frac{5R}{2}\,\ell n\frac{600}{300} = -R\,\ell n\frac{1}{P_2} \quad \Rightarrow \quad \ell n\,P_2 = \frac{5}{2}\times 0.7 = 1.75\,atm$$

46.(C) PV = nRT $\frac{P_1}{n_1} = \frac{P_2}{n_2}$



But $P_1 < P_2$, hence $n_1 < n_2$ or $m_1 < m_2$

47. **(A→p, r; B→ s; C→ q; D→ q;)**

(A) For isothermal reversible process,

$$w = -2.303\,nRT\log\frac{P_1}{P_2} = -2.303\,nRT\log\frac{V_2}{V_1}$$

(B) $w = \frac{nR}{\gamma - 1}\left(T_2 - T_1\right)$ **(C)** $w = 0$ **(D)** $w = 0$

48.(ACD) For O_2

$C_v = \frac{5R}{2} = 5\,\text{cal}$, $C_p = \frac{7R}{2} = 7\,\text{Cal}$

$C_p = \frac{R\gamma}{\gamma - 1}$, $C_v = \frac{R}{\gamma - 1}$

49.(A) $W = -P\Delta V = -nR\Delta T = -R$

50.(B) ΔH is $+\text{ve}$, even then it is spontaneous as ΔS is $+\text{ve}$

51.(B) At equilibrium $\Delta G = 0 \Rightarrow \Delta H = T\Delta S$

52.(A) $\Delta H = \Delta U + \Delta(PV)$

At constant pressure

$\Delta H = \Delta U + P\Delta V$

53.(D) I is incorrect

54.(B) $\Delta U = 0$ for an isothermal process for an ideal gas

55.(D) According to Joule Thomson effect, hydrogen gas get heated when expand adiabatically

56.(C) II is correct because for a spontaneous process, ΔG should be negative

57.(A) Both are correct

58.(B) Both are correct but not correct explanation

59.(C) ΔH for formation of O_2 is zero but the entropy of formation of O_2 is non-zero

60.(C) II statement is incorrect as endothermic reaction can also be spontaneous

61.(B) Both are correct

62.(A) Enthalpy of formation is negative

63.(E) Pressure is an intensive property

Extensive properties depend only on amount of the substance

64.(E) In vacuum, work done is zero

Work done depend on external pressure

65.(A) $q = 0$, $w = -ve$, $\Delta U = -ve$

66.(A) $\Delta U = 0$ for cyclic process

67.(B) $\Delta G = \Delta H - T\Delta S$

68.(C) $\Delta G = \Delta H - T\Delta S$

69.(A) $C_2H_5OH(\ell) + 3O_2(g) \longrightarrow 2CO_2(g) + 3H_2O(\ell)$

$\Delta n_g = 3/2 = -1$

So $\Delta U = \Delta H - \Delta n_g\, RT = -q + RT$

70.(C) For same amount of gas at constant temperature, lesser is the volume lower will be the entropy.

71.(B) $\Delta_r H = \frac{8}{9} \times 45.54 + \frac{1}{9} \times 68.91 = 48.137$ kJ

72.(A) $\Delta_r S^o(NH_4Cl, s)$ at 300 K

$$= S^o_{NH_4Cl(s)} - \left[\frac{1}{2}S^o_{N_2} + 2S^o_{H_2} + \frac{1}{2}S^o_{Cl_2}\right] = -374\ JK^{-1}mol^{-1}$$

$\Delta_r C_p = 0$

$\therefore \quad \Delta_f S^o_{310} = \Delta_f S^o_{300} = -374\ JK^{-1}mol^{-1}$

$\Delta_f H^o_{310} = \Delta_f H^o_{300} = -314.5$

$$\Delta_f G^o_{310} = \Delta_f H^o - 310\Delta S^o = -314.5 - \frac{310(-374)}{1000} = -198.56\ kJ/mol$$

73.(A) BC is a straight line & equation can be obtained by using

$$(y - y_1) = \frac{y_2 - y_1}{x_2 - x_1}(x - x_1)$$

$$(P - 3P^o) = \frac{P^o - 3P^o}{2V^o - V^o}(V - V^o) \Rightarrow (P - 3P^o) = -\frac{2P^o}{V^o}(V - V^o)$$

Replacing P by t by using $P = \frac{RT}{V}$ in equation (1)

$$\left(\frac{RT}{V} - 3P^o\right) = -\frac{2P^o}{V^o}(V - V^o) \Rightarrow T = \frac{2P^oV(V - V^o)}{V^oR} + \frac{3P^oV}{R}$$

For T be maximum

$$\frac{dT}{dV} = 0$$

$$\frac{dT}{dV} = -\frac{2P^o(2V - V^o)}{V^oR} + \frac{3P^o}{R} = 0 \Rightarrow V = \frac{5}{4}V^o$$

$$T_{max} = -\frac{2P^o\frac{5}{4}V^o\left(\frac{5}{4}V^o - V^o\right)}{V^oR} + \frac{3P^o\frac{5}{4}V^o}{R} = \frac{25}{8}\left(\frac{P^oV^o}{R}\right)$$

74.(B) $HA \xrightarrow{\quad} H^+ + A^-; \Delta H = 1.4$ kJ/mol

$$\Delta H_{neutralization} = \Delta H_{ionization} + \Delta_r H \text{ of } (H^+ + OH^- \to H_2O)$$

$$-55.95 = \Delta H_{ionization} - 57.3$$

$\Delta H_{ionization}$ for 1 M HA = 1.35 kJ/mol

$$\text{\% heat utilized by 1 M acid for ionization} = \frac{1.35}{1.4} \times 100 = 96.43\%$$

So, acid is 100 – 96.43 = 3.57% ionized.

75.(B) $0.42 = a(10)^3 \Rightarrow \quad a = 0.42 \times 10^{-3}$

$$S_m = \int_0^{10} \frac{C_{p.m.}}{T} dT = \int_0^{10} aT^2 = \frac{a}{3}[10^3 - 0] = \frac{0.42}{3} = 0.14 \text{ J/K-mol}$$

76.(BC) If the initial and final temperature is equal, it does not imply the process is isothermal. The gas can initially be heated and then cooled to bring it to the same value.

77.(B) $G = H - TS$

$dG = dH - d(TS)$

$\quad = dH - d\,(10T + 10^{-2}\,T^2)$

$$\Delta G = \Delta H - \Delta(10T + 10^{-2}T^2) = nC_p(T_2 - T_1) - 10(T_2 - T_1) - 10^{-2}(T_2^2 - T_1^2)$$

$$n = \frac{PV}{RT} = \frac{24.6}{0.0821 \times 300} = 1$$

$$C_P = \frac{5R}{2}$$

$\Delta G = 378.5$ J

78.(ABC) (A) ΔE will be –ve for combustion reactions

(B) ΔH_f^o (S, rhombic) = 0

(C) $CH_4(g) \xrightarrow{\quad} C(g) + 4H(g) \qquad \Delta H = 1656 \text{ kJ/mole} = 4\Delta H_{C-H}$

$C_2H_6(g) \xrightarrow{\quad} 2C(g) + 6H(g) \qquad \Delta H = 2812 \text{ KJ/mole} = 6\ \Delta H_{C-H} + \Delta H_{C-C}$

So $\Delta H_{C-C} = (2812 - \frac{6}{4} \times 1656)$ kJ/mole = 328 kJ/mole

(D) Can not be concluded from given data.

79.(C)

80.(ABCD) (A) Reversible adiabatic process is isoentropic

(B) Reaction is spontaneous, need not be exothermic

(C) Only when PV work is involved

(D) $\Delta S_{system} = \dfrac{\Delta H_{system}}{T_b} = -\dfrac{40600}{373 \times 2} = -54.42$ J/K

81.(AB) The given reaction will be spontaneous when ΔG woluld be negative when $\Delta H - T\Delta S$ is negative. Then is, $\Delta H - T\Delta S < 0$

$$\text{or} \quad T\Delta S > \Delta H \quad \text{or} \quad T > \frac{\Delta H}{\Delta S} \quad \text{or} \quad T > \frac{61170 \text{ J mol}^{-1}}{132 \text{ JK}^{-1}\text{mol}^{-1}} \quad \text{or} \quad T > 463.4 \text{ K}$$

82.(ABCD)

$$S_{200(B)} = \int_0^{200} \frac{C_P\ dT}{T} = 7\ \text{J mol}^{-1}\ \text{K}^{-1}$$

$$S_{200(\ell)} = 7 + \frac{7500}{200} = 44.5\ \text{J mol}^{-1}\ \text{K}^{-1}$$

$$S_{300(\ell)} = 44.5 + \int_{200}^{300} \frac{C_P\ \ dT}{T} = 4 = 44.5 + 60\ \ln\frac{300}{200} + 1.6 = 70.43\ \text{J mol}^{-1}\ \text{K}^{-1}$$

$$S_{300(g)} = 70.43 + \frac{3000}{300} = 170.453\ \text{J mol}^{-1}\ \text{K}^{-1}$$

$$S_{600(g)} = 170.43 + 50\ \ln\frac{600}{300} = 205.09\ \text{JK}^{-1}\ \text{mol}^{-1}$$

83.(–6) (i) 20L atm (ii) W2 = 0 $(0 \times \Delta V = 0)$ (iii) –6 L atm

(i) State A to state B (Isobaric expansion)

Work done by the gas $= W_1 == -p(V_B - V_A) = -1(40 - 20) = -20\text{L atm}$

(ii) State B to state C (isochoric process)

Work done by the gas $= W_2 = 0(0 \times \Delta V = 0)$

(iii) State C to state A (isothermal compression)

Work done on the gas $= W_3 = -2.303\ \text{nRT}\ \log\frac{V_A}{V_C}$

$$= -2.303\text{pV}\log\frac{V_A}{V_C}(\text{pV} = p_A V_A = p_B V_B = \text{mRT} = 20) = -20\,\ell n(1/2) = 20\text{x}\ \ell n(2) = 14$$

∴ total work done by the gas $= W_1 + W_2 + W_3 = -20 + 0 + 14 = -\ 6\text{L atm}$

84.(A) (a) $0.25 \times 2808 \times \frac{x}{180} \times 10^3 = 62.5 \times 9.81 \times 3$

$x = 0.47$ gm.

(b) $0.25 \times 2808 \times 10^3 \times \frac{y}{180} = 62.5 \times 9.81 \times 3000$

$y = 470$ gm, ⇒ $y = 0.47$ kg

$X = my$ ⇒ $0.47 = m \times 0.47$ ⇒ $m = 1$

85.(6) $W = -P_{ext}(V_f - V_i) = -(1\ \text{atm})(8 - 2)\ \text{L} = -6\text{L atm}$

as q = 0 so

$\Delta E = W$ ⇒ $3(8P_f - 12) = -6$

$8P_f = 12 - \frac{6}{3} = 10$ ⇒ $P_f = \frac{5}{4}$ atm

So, $\frac{T_f}{T_i} = \frac{\frac{5}{4} \times 3}{\frac{4}{6} \times 2} = \frac{10}{12}$

So $\Delta S = 3\frac{12}{300}\ \ln\left(\frac{10}{12}\right) + \frac{12}{300}\ \ln\ 8 = \frac{3 \times 12}{300}\ln\left(\frac{5}{6} \times 2\right) = \frac{12}{100}\ln\left(\frac{5}{3}\right) \times 100\ \text{J}$

$$= 12(\ln 5 - \ln 3) = 12 \times 2.3 \times (0.7 - 0.48) = 12 \times 2.3 \times 0.22 = 6.072\ \text{J/K} = 6\ \text{J/K}$$

86.(0) In isothermal reversible process.

$$\Delta S = \frac{q_{rev}}{T}$$

$$q = -w = 2.303\ RT\ \log\frac{V_2}{V_1} = 2740.6\ J/mole$$

$$\Delta S_{surr.} = \frac{q_{rev.}}{T} = \frac{2740.6}{300} = 9.135\ J/K\ mole$$

$$\Delta S_{surr.} = -\Delta S_{system} = -9.135\ JK^{-1}\ mole^{-1}$$

$$\Delta S_{universe} = 0$$

87.(B) $\Delta H^o = H\left[CaSO_4.\frac{1}{2}H_2O(s)\right] + H\left[\frac{3}{2}H_2O(g)\right]$

$-H[CaSO_4.2H_2O(s)] = 833\ kJ\ mol^{-1} = +\ 484\ kJ$ for 1 kg

88.(C) $\Delta H^o = \Delta H^o - \Delta S^o = 17920\ J\ mol^{-1}$

$$\Delta G^o = -2.303\ RT\ \log K_p$$

$$\log K_p = \frac{\Delta G^o}{2.303\ RT} = 7.22 \times 10^{-4}\ (P_{H_2O})^{3/2}$$

$$P_{H_2O} = 8.1 \times 10^{-3}\ atm$$

89.(A) $P_{H_2O} = 1, K_P = 1$

$\Delta G^o = 0$ at eqm

$$\Delta H^o = T\Delta S^o \Rightarrow T = \frac{\Delta H^o}{\Delta S^o} = 380K = 107^oC$$

90.(B) $-q_c = q_h\left(\frac{Tc}{T_h}\right) = 150 \times \frac{200}{1000}$

Heat rejected = 30 kJ

91.(C) $\Delta S = \frac{q_{rev}}{T} = \frac{q_h}{T_h} = \frac{150 \times 10^3}{1000} = 150\ JK^{-1}$

92.(B) $\Delta G = \Delta H - T\Delta S$

$\Delta H = 0; \Delta S = 150\ JK^{-1}$

$\Delta G = -150\ kJ$

93. – 1368 kJ mol⁻¹

94. $q_1 > q_2$

95. $n_{water\ gas} = \frac{112}{22.4} = 5\ moles$

$\Rightarrow$ Heat evolved $= 2.5 \times 241.8 + 2.5 \times 283 = 1312\ kJ$

96. Energy $= \frac{5}{8} \times 40 + \frac{3}{8} \times 50 = 43.75\ kJ$

97.(C) At equilibrium, $\Delta G = 0$

In (D) option $\Delta ng \neq 0 \quad \Rightarrow \quad \Delta H \neq \Delta E$

98.(D) $\Delta H = \Delta U \qquad \left(\Delta n_g = 0\right)$

$\therefore \quad \Delta U = -185 \times 2$ (For 2 moles)

$= -370\,\text{kJ}$

99.(D) $\Delta H = \Delta E + \Delta n_g RT$

In (D) option $\Delta n_g \neq 0 \Rightarrow \Delta H \neq \Delta E$

100.(C) $\Delta H - \Delta U = \Delta n_g RT$

$$C_8H_{18}(\ell) + \frac{25}{2}O_2(g) \longrightarrow 8CO_2(g) + 9H_2O(\ell)$$

$= -4.5 \times 8.314 \times 10^{-3} \times 298\,\text{kJ} = -11.15\,\text{kJ}$