Numerical problems based on first law of thermodynamics

B.Sc . Part- I. (Physics honours& Subsidiary)

By

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Numerical problems based on first law of thermodynamics

Ex. 1:- **The volume of steam produced by 1 *g* of water at 100^0C is 1650 cm^3. Calculate the change in internal energy during the change of state. Given $J = 4.2\times10^7$ *erg. cal*$^{-1}$, $g = 981$ *cm* s^{-2}, Latent heat of steam = 540 *cal*, g^{-1}.**

***Sol**^{n}:-* **Here, mass of water = 1 g**

□ Initial volume of water, $V_1 = 1\ cm^3$

Volume of steam, $V_2 = 1650\ cm^3$

Change of internal energy, dU = ?

As the state of water is changing

□ dQ = mL = 1 × 540 *cals*.

= $540 \times 4.2 \times 10^7$ *ergs*.

= 22.68×10^9 *ergs*.

Taking P = 1 atmosphere

$$= 76 \times 13.6 \times 981 \ dyne \ cm^{-2}$$

$$dW = P \, dV = P(V_2 - V_1)$$

$$= 76 \times 13.6 \times 981 \ (1650 - 1)$$

$$= 76 \times 13.6 \times 981 \times 1649 \ ergs.$$

$$= 1.67 \times 10^9 \ ergs.$$

As,

$$dQ = dU + dW$$

$$\therefore dU = dQ - dW$$

$$= 22.68 \times 10^9 - 1.67 \times 10^9$$

$$dU = 21.01 \times 10^9 \ ergs.$$

Ex. 2:- **1 *g* of water at 373 *K* is converting into steam at the same temperature. The volume of 1 cm^3 of water becomes 1671 cm^3 on boiling. Calculate change in internal energy of the**

system if heat of vaporization is 540 *cal.* g^{-1}, Given standard atmosphere pressure is 1.013 × 105 Nm^{-2}.

Sol^n*:-** **Here, mass of water, m = 1 *g

∴ Initial volume of water, $V_1 = 1\ cm^3$

Volume of steam, $V_2 = 1671\ cm^3$

∴ Change in volume, $dV = V_2 - V_1$

$$= 1671 - 1 = 1670\ cm^3$$

$$= 1670 \times 10^{-6}\ m^3$$

Standard atmosphere pressure,

$$P = 1.013 \times 10^5\ Nm^{-2}$$

As change of state is involved,

$$\therefore dQ = m\,L = 1 \times 540 \times 4.18\ \text{J}$$

$$= 2257\ \text{J}$$

Change in internal energy, *dU* = ?

$$dW = P\,dV$$

$$= 1.013 \times 10^5 \times 1670 \times 10^{-6}$$

$$= 169\,.\,17 \text{ J}$$

From $dQ = dU + dW$

$$dU = dQ - dW$$

$$= 2257 - 169.17$$

$$dU = 2087.83 \text{ J}$$

Ex. 3:-

Calculate work done to compress isothermally 1 *g* of hydrogen gas at N.T.P. to half its initial volume. Find the amount of heat evolved and change in internal energy.

Given R = 8.31 J $mole^{-1}\,K^{-1}$.

***Sol^n*:-**

$$W = 2.3026\left(\frac{R}{M}\right)T\log_{10}\left(\frac{V_2}{V_1}\right)$$

$$= 2.3026 \times \frac{8.31}{2} \times 273 \log\left(\frac{1}{2}\right)$$

$$W = -786.2 J$$

Amount of heat evolved

$$= \frac{786.2}{4.2} cal$$

$$= 187.2 \, cal$$

As the change is isothermal, temperature remains constant. Internal energy of the gas also remains constant. Hence change in internal energy is zero.

Ex. 4:- **Water of 1 *kg* mass at 373 *K* is converted into steam at the same temperature. On boiling, 1 *c.c.*, of water takes a volume of 1671 *c.c.*, Calculate the change in internal energy of the system, taking the heat of vaporization to be 540 $cal.\,g^{-1}$.**

***Sol^n*:-**

Here, $m = 1\ kg = 10^3\ g$

∴ Initial volume, $V_1 = 10^3\ c.c.$,

Final volume, $V_2 = 1671 \times 10^3\ c.c.$,

P = atmosphere

$= 1.013 \times 10^6\ dyne/cm^2$

From first law of thermodynamics

$$dU = dQ - dW = mL - P(V_2 - V_1)/J$$

$$= 10^3 \times 540 - \frac{1.013 \times 10^6 \times 10^3 (1671 - 1)}{4.2 \times 10^7}$$

$$dU = 540 \times 10^3 - 40.16 \times 10^3$$

$$= 499.84 \times 10^3\ cal. = 499.84\ k\,cal.$$

Thank You

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