

## *Revision*

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# *First Law of Thermodynamics*

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**Question** *State whether right or wrong*

**Both mass and density of a gas are extensive properties ?**

**Answer**

**X:** *mass is an extensive  
but density is an intensive  
property*

**Question** *State whether right or wrong*

**Joule experiment can be applied for perfect gas only ?**

**Answer**



**Question** *State whether right or wrong*

**4 moles of an ideal gas expands isothermally and reversibly from 2 L to 10 L, the work done under this condition is -4 J?**

**Answer**

$$\begin{aligned}
 W_b &= -\int_1^2 P dV = -\int_1^2 \frac{nRT_0}{V} dV = -nRT_0 \int_1^2 \frac{dV}{V} = \\
 &= -nRT_0 \ln \frac{V_2}{V_1} = -P_1 V_1 \ln \frac{V_2}{V_1} = -P_2 V_2 \ln \frac{V_2}{V_1} \\
 &= -P_2 V_2 \ln \frac{P_1}{P_2}
 \end{aligned}$$

**X:** *missing information*

**Question** *State whether right or wrong*

✚ *The ratio between heat capacities at constant pressure and at constant volume for  $\text{NH}_3$  equals 1.67?*

**Answer**

✘:  *$\text{NH}_3$  is not a monoatomic gas. It will be less*

**Question** *State whether right or wrong*

✚ *The rate of decreasing  $P$  with  $V$  for a gas under isothermal conditions is steeper than that under adiabatic conditions?*

**Answer**

✘: *the reverse is true*

**Question** *State whether right or wrong*

✚ The state function is independent of the initial and final states but is path dependent?

**Answer**

✘: is path independent

**Question** *State whether right or wrong*

✚ A system containing 2 moles of  $\text{CO}_2$  ( $c_p = 41 \text{ JK}^{-1}\text{mol}^{-1}$ ) at 400 K is heated by 2 kJ at constant pressure, the final temperature will be 424K?

**Answer**

$$T_2 = 424.39\text{K}$$

✓

$$\begin{aligned} q_p &= 2 \times 10^3 \text{ J} = n c_p \Delta T \\ &= (2 \text{ mol}) \left( \frac{41 \text{ J}}{\text{Kmol}} \right) (T_2 - 400\text{K}) \end{aligned}$$

**Question** *State whether right or wrong*

✚ *At inversion temperature, neither heating nor cooling occurs for a real gas?*

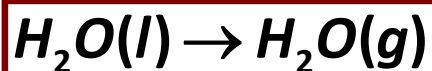
**Answer**



**Question** *State whether right or wrong*

✚ *For evaporation of one mole of water at 100 °C and 1 atm, the work done equals ~ 100 J?*

**Answer**



*Const. P*  $W = -P(V_2 - V_1) \approx -PV_2 = nRT$

$$W = -(1\text{mol})(8.314\text{ JK}^{-1}\text{ mol}^{-1})(373.15\text{ K}) = -3.1\text{kJ}$$



**Question** *State whether right or wrong*

✚ The work done by the gas adiabatically is

$$W = -P_{ext} (V_2 - V_1) \quad ?$$

**Answer**

$$W = \Delta U = nC_v (T_2 - T_1)$$

✗

**Question**

*Write the mathematical expression for*

✚ Kirschoff's equation

**Answer**

$$\int_{\Delta H_1}^{\Delta H_2} d\Delta H = \int_{T_1}^{T_2} \Delta C_p dT$$

Assuming  $\Delta C_p$  is independent of  $T$  in the assigned domain (between  $T_1$  and  $T_2$ ) therefore,

$$\Delta H_2 - \Delta H_1 = q_p = \Delta C_p (T_2 - T_1)$$

**Question**

Write the mathematical expression for

✚ **Joule-Thomson coefficient**

**Answer**

$$\mu = \left( \frac{\partial T}{\partial P} \right)_H$$

$$\mu = -\frac{1}{C_p} \left( \frac{\partial H}{\partial P} \right)_T = -\frac{1}{C_p} \left( \frac{\partial (U + Pv)}{\partial P} \right)_T$$

$$\mu = -\frac{1}{C_p} \left( \frac{\partial U}{\partial P} \right)_T - \frac{1}{C_p} \left( \frac{\partial Pv}{\partial P} \right)_T$$

**Question**

Write the mathematical expression for

✚ **Heat of reaction at constant pressure and that at constant volume**

✚ **For ideal gases: (constant n)**  
(T is not constant), eg.,  
expansion or compression in  
a closed system

✚ **For ideal gases: (constant T)**  
(n is not constant), eg., a  
chemical reaction or a  
vaporization process

**Answer**

$$\begin{aligned} \Delta H &= \Delta U + \Delta nRT \\ &= \Delta U + nR\Delta T \end{aligned}$$

$$\begin{aligned} \Delta H &= \Delta U + \Delta nRT \\ &= \Delta U + RT\Delta n \end{aligned}$$

**Question**

*Write the mathematical expression for*

**+Free work of expansion**

**Answer**

**Expansion against vacuum,**

$$W = -P_{ext} (V_2 - V_1) = 0$$

**Question**

*Write the mathematical expression for*

**+PV-relationship for adiabatic processes**

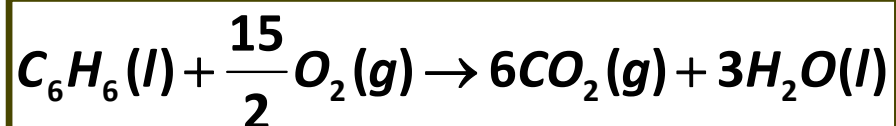
**Answer**

$$P_1 V_1^\gamma = P_2 V_2^\gamma$$



## Solve this problem

✚ Calculate the difference between heats of a reaction at constant pressure and that at constant volume for the combustion of one mole of benzene at 25 °C according to the equation



**Solution**

$$\Delta n = 6 - 7.5 = -1.5 \text{ mol}$$

$$\Delta H = \Delta U + RT \Delta n$$

$$\Delta H - \Delta U = RT \Delta n$$

$$= \left( \frac{8.314 \text{ J}}{\text{K mol}} \right) (298 \text{ K}) (-1.5) \left( \frac{1 \text{ kJ}}{1000 \text{ J}} \right)$$

$$\Delta H - \Delta U = -3.716 \text{ kJ}$$

## Solve this problem

4 mole of  $\text{CO}_2$  gas are expanded isothermally and reversibly from 3L to 5L at 25 °C. Calculate  $q$  and  $\Delta U$ ?

**Answer**

$$W_{rev} = -nRT \ln \frac{V_2}{V_1} =$$

$$\left( -(4 \text{ mol})(8.314 \text{ JK}^{-1} \text{ mol}^{-1})(298 \text{ K})(2.303) \log \left( \frac{5}{3} \right) \right)$$

$$= -5063 \text{ J} = -5.063 \text{ kJ}$$

*Isothermally??*

$$\Delta U = 0$$