First Law of Thermodynamics Chemistry Questions with Solutions

Q1: ΔU = 0 means that the process is isothermic. True or False?
a) True
b) False

Answer: a) True

Explanation: Temperature is the only factor that affects internal energy. As a result, if ΔU = 0, the process will have a constant temperature or be isothermic.

Q2: Temperature is developed during a fluid flow as a result of________.
a) Increase in density
b) Change in pressure
c) Fluid level
d) Translational Kinetic Energy

Answer: d) Translational Kinetic Energy

Explanation: When a high rate of fluid flow is present, the molecules are more likely to clash. The average translational kinetic energy of the particles increases in this state. The temperature established due to this is called Kinetic temperature.

Q3: When enthalpy increases, the _________ rises as well.
a) Internal energy
b) Volume
c) Pressure
d) Mass

Answer: a) Internal energy

Explanation: The number of molecular interactions increases as the temperature increases. According to the equation from the first rule of thermodynamics, internal energy increases with temperature. As a result, as enthalpy rises, internal energy rises as well.

Q4: Which of these reactions isn't exothermic?
a) Combustion reaction
b) Neutralization reaction
c) Evaporating liquid water
d) Thermite reaction

Answer: c) Evaporating liquid water

Explanation: An exothermic reaction releases energy in the form of light or heat. Endothermic reactions are the polar opposite of exothermic processes. Evaporating liquid water is an endothermic reaction in this situation. Endothermic reactions take place when a system consumes heat from its environment.

Q5: During photosynthesis, what reaction occurs?
a) Endothermic reaction
b) Exothermic reaction
c) Redox reaction
d) Combustion reaction

Answer: a) Endothermic reaction

Explanation: Photosynthesis involves the absorption of heat and energy from the environment. The reaction that occurs during photosynthesis is an endothermic reaction because it is a response in which the system absorbs heat from its environment.

Q6: What is the entropy equation?
a) Ratio of absolute temperature to reversible heat transfer
b) Ratio of reversible transfer of heat to absolute temperature
c) Ratio of adiabatic heat to macroscopic variables
d) Ratio of macroscopic variables to adiabatic heat

Answer: b) Ratio of reversible transfer of heat to absolute temperature

Explanation: Rudolf Clausius established this equation by defining entropy as the ratio of reversible heat transfer to absolute temperature. This concept of entropy is also known as the macroscopic definition.

Q7: Calculate the final volume of one mole of an ideal gas at 0°C and 1 atm pressure. During reversible isothermal expansion, it absorbs 2000 calories of heat.

Answer:

The gas is at standard temperature and pressure, i.e. it is at STP.

As a result, $V_1 = 22.4\ dm^3$ and V_2 must be determined.

Assuming that the expansion is isothermal and reversible, $\Delta U = 0$.

We know that $\Delta U = q + w$
But $\Delta U = 0$
Thus, $q = -w = 2000$ cal

= 2000 x 4.184 J = 8368 J

w = −nRT In (V_2/ V_1) is the work done in reversible isothermal expansion.

∴ nRT In (V_2/ V_1) = – w = 8368 J

⇒ (I mol) x (8.314 J K^- mol^-) x (273 K) In (V_2/ 22.4 dm^3) = 8368 J

⇒ **V_2 = 242.50 dm^3**

As a solution, one mole of an ideal gas at 0°C and 1 atm pressure has a final volume of 242.50 dm^3.

Q8: Give the limitations of the First Law of Thermodynamics.

Answer:

Limitations of the first law of thermodynamics are as follows:

- There are no constraints on the flow of heat in either direction: the first law provides a direct relationship between the heat received and the work done by a system. The first law does not state whether or not heat can travel from a cold to a hot end. For example, chilling ice to a low temperature will not allow us to extract heat from it. There is some external work that remains to be done.

- Does not indicate if the reaction is possible: the first law does not specify whether a process is feasible or not. For example, when a rod is heated at one end, equilibrium must be achieved, which is only attainable with some energy expenditure.

- It is not possible to convert heat energy into an equivalent quantity of work in practise.

Another law, known as the second law of thermodynamics, is required to overcome these limitations.

Q9: In an isothermal process, the first law of thermodynamics states that-

(a) the internal energy of the system fluctuates and there exists an imbalance between work and heat
(b) a constant amount of heat is added to the system
(c) temperature is not affected by the internal energy of the system, work, or heat
(d) it can be implied that heat added to the system is equal to work done by the system
(e) temperature is not affected by the pressure or volume changes of the system

Answer: (d) it can be implied that heat added to the system is equal to work done by the system

Explanation: The difference between the heat energy added to the system and the work done by the system, according to the first law of thermodynamics, determines the change in internal energy of a closed system:

$\triangle U = Q - W$

Temperature remains constant in an isothermal process. The temperature of a system is a measure of its internal energy. There is no variation in internal energy if the temperature is constant.

$0J = Q - W$

It can be assumed that the amount of heat added to the system equals the amount of work done by the system.

$Q = -W$

Q10: Compare Isothermal Expansion and Adiabatic Expansion.

Answer:

Assume that isothermal and adiabatic expansions of an ideal gas have the same initial volume $\mathbf{V_i}$ and pressure $\mathbf{P_i}$, leading to the same end volume $\mathbf{V_f}$. If the final pressures are $\mathbf{P_{iso}}$ and $\mathbf{P_{adia}}$, then:

For the purpose of isothermal expansion, $\mathbf{P_i V_i = P_{iso} V_f}$

And for adiabatic expansion, $\mathbf{P_i V^{\gamma}_i = P_{adia} (V_f)^{\gamma}}$

As a result, $\mathbf{V_f/V_i = P_i/P_{iso}}$

And $\mathbf{V_f/V_i = P_i/P_{adia}}$

As for expansion $(V_f) > (V_i)$ and also for all gases $\gamma > 1$, hence

$\{(V_f/V_i)^{\gamma}\} > \{V_f/V_i\}$

Therefore, $\{P_i/P_{adia}\} > \{P_i/P_{iso}\}$

Alternatively, $\mathbf{(P_{adia}) < (P_{iso})}$.

Q11: Define the enthalpies of vaporisation and fusion.

Answer:

Enthalpy of Vaporisations: Some heat is absorbed from the surroundings during the evaporation of a liquid. As a result, an increase in enthalpy is required for liquid evaporation.

While evaporating one mole of water at 25°C, the increase in enthalpy is 43.93 kJ.

This result can be expressed in the form of thermo-chemical equation which is given below:

$H_2O(l) \rightarrow H_2O(g)$; $\Delta H = +\ 43.93$ kJ

The evolution of heat occurs when vapours condense into liquid state. As a result, a drop in enthalpy causes liquid to condense.

The enthalpy decreases by 43.93 kJ when one mole of water vapour is condensed at 25°C. Therefore,

$H_2O(g) \rightarrow H_2O(l)$; $\Delta H = -\ 43.93$ kJ

Enthalpy of Vaporization is the change in enthalpy (ΔH) when a liquid transforms into a vapour and a vapour transforms into a liquid.

Enthalpy of Fusion: Liquid is formed when melting of solid takes place. The absorption of heat occurs during this time.

The system's enthalpy rises as a result of this. While fusing one mole of water at 0°C, the increase in enthalpy is 6.02 kJ.

It is as follows:
$H_2O(s) \rightarrow H_2O(l)$; $\Delta H = +\ 6.02$ kJ

When a liquid freezes and transforms into a solid state, heat is emitted. As a result, the enthalpy of the process drops, i.e.
$H_2O(l) \rightarrow H_2O\ (s)$; $\Delta H = -\ 6.02$ kJ

Enthalpy of Fusion is defined as the change in enthalpy, i.e. ΔH, when a solid becomes a liquid and a liquid becomes a solid.

Q12: What are the various forms of Energy?

Answer:

The various forms of Energy are:

- **Heat Energy**

A transfer (flow) of thermal energy across a boundary (for example, from a hot body to a cold body via the area of their contact) is defined as heat. Heat is defined as energy that transfers from a high-temperature item to a lower-temperature object. The energy in an object is referred to as its internal energy rather than "heat." The action of heating might increase this internal energy.

A temperature difference causes heat energy to be transferred. A warm body with a higher temperature transfers energy as heat to a cold body with a lower temperature.

Heat flow is the transmission of energy that occurs only as a result of a temperature differential. The SI unit of power, the Watt, can be defined as 1 J/s of heat flow. Calorie is another unit used to measure heat energy.

- **Chemical Energy**

Chemical energy is the energy derived from the interactions of atoms in molecules and other types of matter aggregation. It is defined as the work done by electric forces during the aggregation process when mutual positions of electric charges, electrons and protons, are rearranged. So, the electrostatic potential energy of electric charges is basically what it is. When a system's chemical energy is reduced during a chemical reaction, the difference is passed to the environment in some way (often heat or light). If, on the other hand, a system's chemical energy increases as a result of a chemical reaction, the difference is filled by the environment (usually again in form of heat or light).

- **Mechanical Energy**

Mechanical energy comes in a variety of forms, but it may be divided into two categories: elastic potential energy and kinetic energy. Potential energy, on the other hand, is a very broad phrase that encompasses all force fields, including gravitation, electrostatics, and magnetic fields. The energy that any object receives as a result of its position in a force field is referred to as potential energy.

- **Electric Energy**

The electric potential energy of a provided configuration of charges is characterised as the work which must be done against the Coulomb force to rearrange charges from infinite separation to this configuration.

Q13: C_2H_2(g), C (graphite), and H_2(g) have molar heats of combustion of 210.62 Kcal, 84.05 Kcal, and 69.32 Kcal, respectively. Calculate the standard heat of formation of C_2H_2(g).

Answer:

The required reaction is: $2C + H_2 \rightarrow C_2H_5$

Standard heat of formation equation, i.e. ΔH =?

Creating a thermochemical equation based on the information provided:

(i) $C_2H_2 + 5/2\ O_2 \rightarrow 2CO_2 + H_2O$, $\Delta H = -210.62$ kcal (given)

(ii) $C + O_2 \rightarrow CO_2$, $\Delta H = -84.05$ kcal (given)

(iii) $H_2 + 1/2\ O_2 \rightarrow H_2O$, $\Delta H = -69.32$ kcal (given)

Now, multiplying (ii) eq. by 2 and then adding (iii) eq. and subtracting (i) eq. i.e.
i.e. (ii) $2C + 2O_2 \rightarrow 2CO_2$, $\Delta H = -168.1$ kcal

As a result, we get the following equation after adding (iii) eq. and subtracting (i) eq.

$2C + H_2 \rightarrow C_2H_2$, $\Delta H = 26.80$ kcal

As a result, **$\Delta H = 26.80$ kcal** is the standard heat for the formation of C_2H_2.

Q14: Define Gibbs Free energy. Also, derive the Relationship between Equilibrium Constant and Gibbs free energy and hence Calculate $\Delta G°$ for conversion of oxygen to ozone $3/2\ O_2\ (g) \rightarrow O_3\ (g)$ at 300 K, if Kp for this conversion is 9.47×10^{-29}.

Answer:

Gibbs free energy: The Gibbs free energy (or Gibbs energy) is a thermodynamic potential that can be used to calculate the maximum reversible work that a thermodynamic system can accomplish at a constant temperature and pressure in thermodynamics. It is symbolised by $\Delta G°$.

Relationship between Free Energy and Equilibrium Constant: When equilibrium is not achieved, the reaction's free energy change in any state is denoted as ΔG, which is related to the reaction's standard free energy change, $\Delta G°$.

$\Delta G = \Delta G° + RT\ lnQ$, where Q is the reaction quotient

When equilibrium is achieved, there is no further change in free energy, i.e. $\Delta G = 0$ and the reaction quotient Q equals the equilibrium constant. As a result, the equation above will appear like this:

$\Delta G° = -RT\ ln\ K_{eq}$

Or, $\Delta G° = -2.303\ RT\ log\ K_{eq}$

Galvanic cells are an example of this. The electrical work done by the cell is related to Gibbs energy change ΔG.

$\Delta G = -nFE_{cell}$, where, n = no. of moles of electrons involved
F = the Faraday constant
E = emf of the cell

When both the reactants and the products are in their standard states,

$\Delta G^\circ = nFE^\circ_{cell}$

$3/2\ O_2(g) \rightarrow O_3(g)$

Now, $\Delta G^\circ = -2.303\ RT \log K_p$

Where R = 8.314 J/K mol, $K_p = 9.47 \times 10^{-29}$, T = 300K

Thus, Gibbs energy, **ΔG° = 160971 J/mol = 160.971 KJ/mol**

Q15: One mole of an ideal gas is heated at constant pressure from 0°C to 200°C.
(a) Calculate the amount of work completed.
(b) What must be the final pressure if the gas is expanded isothermally and reversibly at 0°C from 1 atm to some other pressure Pt if the maximum work is equal to the work involved (a).

Answer:

(a) Work done:

Work done during the heating of gas from 0 to 200°C.

$T_1 = 0°C = 273\ K$
$T_2 = 200°C = 473\ K$
Now

$W = -P\Delta V = -P(V_2 - V_1)$
$= -P[(nRT_2/P) - (nRT_1/P)]$

$= -nR(T_2 - T_1) = -1 \times 1.987 \times (473 - 273)$

= – 397.4 cal

(b) If 397.4 cal of work is applied to a gas at 0°C to cause isothermal expansion from 1 atm to pressure Pt, the work done in reversible isothermal expansion is:

$w = -2.303nRT\log(P_1/P_2)$

–397.4 = – 2.303 × 1.987 × 273log (1/Pt)

Therefore, Pt = 1.272 atm

Hence, final pressure is **0.694 atm**.

Practise Questions on First Law of Thermodynamics

Q1: First law of thermodynamics is based on?
a) Conservation of energy
b) Conservation of mass
c) Conservation of momentum
d) Conservation of work

Answer: a) Conservation of energy

Explanation: The first law of thermodynamics is based on the conservation of energy. It is concerned with the amount of work done and the amount of heat energy supplied or removed from a system. It essentially states that the energy delivered to a system is conserved.

Q2: The equation for the average kinetic energy is__________
a) 0.5 KT
b) 2.5 KT
c) 1.5 KT
d) 3.5 KT

Answer: c) 1.5 KT

Explanation: The kinetic energy equation is $0.5mv^2$, where m is mass and v is velocity. This equation equals 1.5 KT, where K denotes Boltzmann's constant and R is the gas constant.

Q3: How is the first law of thermodynamics applied in chemistry?

Answer:

According to the first law of thermodynamics, energy cannot be created or destroyed, implying that the universe's energy is constant. This enables us to define a thermodynamic system, which in chemistry is a reaction, with everything else being the surroundings.

Q4: The first law of thermodynamics is represented by which of the following?
(a) While melting, an ice cube remains at the same temperature
(b) If a refrigerator is unplugged, eventually, everything inside of it will return to room temperature

(c) The specific heat of an object explains how easily it changes temperatures
(d) Two systems in equilibrium with a third system are in equilibrium with each other
(e) After falling down the hill, a ball's kinetic energy plus heat energy equals the initial potential energy

Answer: (e) After falling down the hill, a ball's kinetic energy plus heat energy equals the initial potential energy

Explanation: The law of conservation of energy is often known as the first law of thermodynamics. According to this theory, energy cannot be created or destroyed, but it can change forms.

This means that the entire initial energy equals the ultimate kinetic energy + heat in the particular condition of the ball rolling down the hill.

According to the zeroth law of thermodynamics, if a system is in equilibrium with two other systems, then the two other systems are in equilibrium with each other.

The entropy of a closed system will always rise, according to the second rule of thermodynamics.

Absolute zero, according to the third rule of thermodynamics, is the temperature at which entropy is zero.

Q5: Show that $\Delta U = 0$ and $\Delta H = 0$ in an Isothermal Expansion of an Ideal Gas.

Answer:

(a) We know that $\mathbf{C_V = (\partial U/\partial T)_V}$, for one mole of an ideal gas.

As a result, $dU = C_V dT$

For a finite change, $\Delta U = C_V \Delta T$

T is constant in an isothermal process, resulting in $\Delta T = 0$.

As a result, given an ideal gas's isothermal expansion, $\mathbf{\Delta U = 0}$.

(b) We already know that, $\Delta H = \Delta U + \Delta(PV)$

As for ideal gas, $PV = RT$

$\therefore \Delta H = \Delta U + \Delta (RT)$

i.e. $\Delta H = \Delta U + R\Delta T = R\Delta T$ (from (a) $\Delta U = 0$)

Since T is constant, $\Delta T = 0$. Hence, Δ**H = 0**.