Chemical Thermodynamics JEE Main PYQ - 3

Total Time: 25 Minute **Total Marks:** 40

Instructions

Instructions

1. Test will auto submit when the Time is up.
2. The Test comprises of multiple choice questions (MCQ) with one or more correct answers.
3. The clock in the top right corner will display the remaining time available for you to complete the examination.

Navigating & Answering a Question

1. The answer will be saved automatically upon clicking on an option amongst the given choices of answer.
2. To deselect your chosen answer, click on the clear response button.
3. The marking scheme will be displayed for each question on the top right corner of the test window.

Chemical Thermodynamics

1. If enthalpy of atomisation for $Br_{2(I)}$ is $x\,kJ/mol$ and bond enthalpy for Br_2 is $y\,kj/mol$, the relation between them : **(+4, -1)**

[Jan.•09,2020•(I)]

a. is $x < y$

b. does not exist

c. is $x > y$

d. is $x = y$

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2. In which of the following exothermic reactions, the heat liberated per mole is the highest ? **(+4, -1)**

[Online•April•25,•2013]

a. $CaO + H_2O \rightarrow Ca\,(OH)_2$

b. $SrO + H_2O \rightarrow Sr\,(OH)_2$

c. $BaO + H_2O \rightarrow Ba\,(OH)_2$

d. $MgO + H_2O \rightarrow Mg\,(OH)_2$

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3. Match List I with List II : **(+4, -1)**

LIST I Isomeric pairs		**LIST II Type of isomers**	
A	Propanamine and N-Methylethanamine	I	Metamers
B	Hexan-2-one and Hexan-3-one	II	Positional isomers
C	Ethanamide and Hydroxyethanimine	II	Functional isomers
D	o-nitrophenol and p-nitrophenol	IV	Tautomers

Choose the correct answer from the options given below:

a. A-II, B-III, C-I, D-IV

b. A-III, B-I, C-IV, D-II

c. A-III, B-IV, C-I, D-II

d. A-IV, B-III, C-I, D-II

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4. The combustion of benzene (l) gives $CO_2(g)$ and $H_2O(l)$. Given that heat of combustion of benzene at constant volume is $-3263.9\,kJ\,mol^{-1}$ at $25^{\circ}C$; heat of combustion (in $kJ\,mol^{-1}$) of benzene at constant pressure will be -$(R = 8.314\,JK^{-1}\,mol^{-1})$ **(+4, -1)**

[2018]

a. 4152.6

b. -452.46

c. 3260

d. -3267.6

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5. Which one of the following reactions does not occur during extraction of copper? **(+4, -1)**

a. $CaO + SiO_2 \rightarrow CaSiO_3$

b. $2Cu_2S + 3O_2 \rightarrow 2Cu_2O + 2SO_2$

c. $FeO + SiO_2 \rightarrow FeSiO_3$

d. $2FeS + 3O_2 \rightarrow 2FeO + 2SO_2$

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7. How many reactions are non-spontaneous at 300 K. For independent reaction ΔH & ΔS values are given. **(+4, -1)**

[Online•April•9,•2016]

a. $\Delta H = -25kJ/mol, \Delta S = -80J/mol$

b. $\Delta H = +25kJ/mol, \Delta S = -50J/mol$

c. $\Delta H = -22kJ/mol, \Delta S = +50J/mol$

d. $\Delta H = -22kJ/mol, \Delta S = 80J/mol$

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8. Given below are two statements: one is labelled as Assertion A and the other is labelled as Reason R **(+4, -1)**

Assertion A: In an Ellingham diagram, the oxidation of carbon to carbon monoxide shows a negative slope with respect to temperature

Reason R: CO tends to get decomposed at higher temperature

In the light of the above statements, choose the correct answer from the options given below

[28-Jul-2022-Shift-2]

a. A is correct but R is not correct

b. A is not correct but R is correct

c. Both A and R are correct and R is the correct explanation of A

d. Both A and R are correct but R is NOT the correct explanation of A

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9. If the standard electrode potential for a cell is 2 V at 300 K, the equilibrium constant (K) for the reaction $Zn(s) + cu^{2+}(aq) <=> Zn^{2+}(aq) + Cu(s)$ at 300 K is approximately. $(R = 8\ JK^{-1}\ mol^{-1}, F = 96000\ C\ mol^{-1})$ **(+4, -1)**

[22•Jul•2021•Shift•2]

a. e^{160}

b. e^{320}

c. e^{-160}

d. e^{-80}

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10. Two moles of an ideal monoatomic gas occupies a volume V at $27^{\circ}C$. The gas expands adiabatically to a volume $2V$. Calculate (a) the final temperature of the gas and (b) change in its internal energy - **(+4, -1)**

a. (a) 189 K (b) 2.7 kJ **[30-Jan-2023•Shift•2]**

b. (a) 195 K (b) - 2.7 kJ

c. (a) 189 K (b) -2.7 kJ

d. (a) 195 K (b) 2.7 kJ

Answers

1. **Answer: c**

Explanation:

Enthalpy of atomisation of $Br_2\,(l)$ $\Delta H_{atoms} = \Delta H_{vap} + \Delta H_{BE}$ $x = \Delta H_{vap} + y$ $so,\, x > y$

Concepts:

1. Thermodynamics:

Thermodynamics in physics is a branch that deals with heat, work and temperature, and their relation to energy, radiation and physical properties of matter.

Important Terms

System

A thermodynamic system is a specific portion of matter with a definite boundary on which our attention is focused. The system boundary may be real or imaginary, fixed or deformable.

There are three types of systems:

- **Isolated System –** An isolated system cannot exchange both energy and mass with its surroundings. The universe is considered an isolated system.
- **Closed System –** Across the boundary of the closed system, the transfer of energy takes place but the transfer of mass doesn't take place. Refrigerators and compression of gas in the piston-cylinder assembly are examples of closed systems.
- **Open System –** In an open system, the mass and energy both may be transferred between the system and surroundings. A steam turbine is an example of an open system.

Thermodynamic Process

A system undergoes a thermodynamic process when there is some energetic change within the system that is associated with changes in pressure, volume and internal

energy.

There are four types of thermodynamic process that have their unique properties, and they are:

- **Adiabatic Process** – A process in which no heat transfer takes place.
- **Isochoric Process** – A thermodynamic process taking place at constant volume is known as the isochoric process.
- **Isobaric Process** – A process in which no change in pressure occurs.
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Laws of Thermodynamics

Zeroth Law of Thermodynamics

The Zeroth law of thermodynamics states that if two bodies are individually in equilibrium with a separate third body, then the first two bodies are also in thermal equilibrium with each other.

First Law of Thermodynamics

The First law of thermodynamics is a version of the law of conservation of energy, adapted for thermodynamic processes, distinguishing three kinds of transfer of energy, as heat, as thermodynamic work, and as energy associated with matter transfer, and relating them to a function of a body's state, called internal energy.

Second Law of Thermodynamics

The Second law of thermodynamics is a physical law of thermodynamics about heat and loss in its conversion.

Third Law of Thermodynamics

Third law of thermodynamics states, regarding the properties of closed systems in thermodynamic equilibrium: The entropy of a system approaches a constant value when its temperature approaches absolute zero.

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2. Answer: a

Explanation:

The correct answer is (A) : $CaO + H_2O \rightarrow Ca(OH)_2$
Due to smaller size of calcium hydration energy will be maximum.

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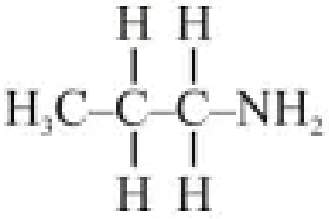
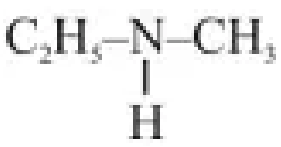
3. **Answer: b**

Explanation:

Correct answer is (b) A-III, B-I, C-IV, D-II

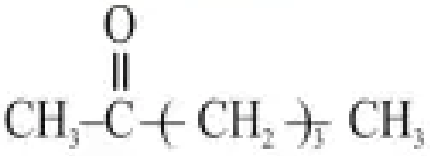
A. Propanamine N–Methylethanamine

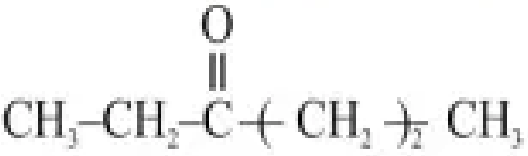




⇒ Functional isomers

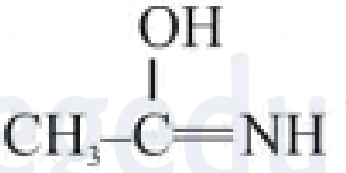
B. Hexan–2–one Hexan–3–one





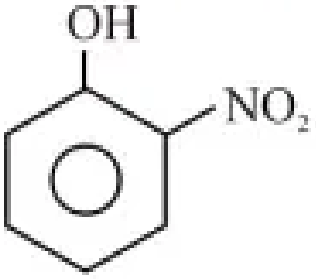
⇒ Metamers

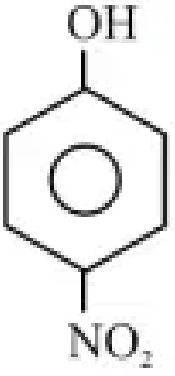
C. Ethanamide Hydroxyethanimine



⇒ Tautomers

D. o–Nitrophenol p–nitrophenol





⇒ Positional isomers

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4. **Answer: d**

Explanation:

$C_6H_6(I) + \frac{15}{2}O_2(g) \longrightarrow 6CO_2(g) + 3H_2O(I)\ \Delta n_g = 6 - \frac{15}{2} = -\frac{3}{2}\ \Delta H = \Delta U + \Delta n_g RT = -3263.9 + \left(-\frac{3}{2}\right) \times 8.314 \times 298 \times 10^{-3} = -3263.9 + (-3.71) = -3267.6\, kJ\, mol^{-1}$

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5. Answer: a

Explanation:

$$CuFeS_2 + O_2 \xrightarrow{\text{Partial roasting}} Cu_2S + FeO + SO_2 + \underset{\text{very small}}{FeS} + \underset{\text{very small}}{Cu_2O}$$

$$Cu_2S + O_2 \; ? \; Cu_2O + SO_2$$

$$FeS + O_2 \; ? \; FeO + SO_2$$

$$FeO + SiO_2 \; ? \; FeSiO_3$$

No formation of calcium silicate $(CaSiO_3)$ in extraction of Cu.

Concepts:

1. General Principles and Processes of Isolation of Elements:

What are Ores and Minerals?

Minerals are the naturally occurring, homogeneous inorganic solid substances. They are having a definite chemical composition and crystalline structure, hardness and color. For example, copper pyrite, calamine, etc.

Difference between Ores and Minerals

S. No.	Ores	Minerals
1.	These are those naturally occurring homogeneous inorganic solid substances from which metal can be economically extracted.	These are naturally occurring homogeneous inorganic solid substances which have a definite chemical composition.
2.	All ores are minerals.	All minerals are not ores.
3.	Zinc blend, bauxite, cinnabar, etc. are examples of ores.	Clay (it's not an ore), horn silver, cryolite, etc. are examples of minerals.

Impurities in an ore are called gauge. The removal of a gauge from the ore is called concentration ore.

Several steps are involved in the extraction of pure metal from ores. Major steps are as follows –

- Concentration of the ore
- Isolation of the metal from its concentrated ore
- Purification of the metal

---

6. Answer: a

Explanation:

$CuFeS_2 + O_2 \xrightarrow{\text{Partial roasting}}$

$Cu_2S + FeO + SO_2 + \underset{\text{very small}}{FeS} + \underset{\text{very small}}{Cu_2O}$

$Cu_2S + O_2 \rightarrow Cu_2O + SO_2$

$FeS + O_2 \rightarrow FeO + SO_2$

$FeO + SiO_2 \rightarrow FeSiO_3$

No formation of calcium silicate $(CaSiO_3)$ in extraction of Cu.

So, the correct option is (A): $CaO + SiO_2 \rightarrow CaSiO_3$

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---

7. Answer: b

Explanation:

A reaction is considered spontaneous at a particular temperature when it exhibits a positive change in Gibbs free energy, denoted as ΔG. The formula for calculating ΔG is $\Delta G = \Delta H - T\Delta S$, where ΔH represents the change in enthalpy, and ΔS represents the change in entropy. A negative ΔG value indicates a spontaneous reaction, while a positive ΔG value indicates a non-spontaneous reaction.

$\triangle H$	$\triangle S$	$\triangle G$	Spontaneity of reaction
Negative (exothermic)	Positive	Negative	Reactions are spontaneous at all temperatures.
Negative (exothermic)	Negative	Negative or Positive	Reactions become spontaneous at low temperatures. when $\|T.\triangle S\| < \|\triangle H\|$.
Positive (endothermic)	Positive	Negative or Positive	Reactions become spontaneous at low temperatures. when $\|T.\triangle S\| < \|\triangle H\|$.
Positive (endothermic)	Negative	Positive	Reactions are non-spontaneous at all temperatures.

Now, let's examine the Gibbs free energy changes for each reaction at a temperature of 300 K:

(A) $\Delta H = -25kJ/mol,\ \Delta S = -80J/mol$

$$\triangle G = \triangle H - T\triangle S$$
$$\triangle G = -25 - 300 \times (\tfrac{-80}{1000})$$
$$= -25 - 300 \times (-0.08)$$
$$= -25 - (-24)$$
$$= -25 + 24$$
$$\triangle G = -1$$

$\Rightarrow \Delta G$ is negative, the reaction is spontaneous.

(B) $\Delta H = +25\,kJ/mol, \Delta S = +50\,J/mol$

$$\triangle G = \triangle H - T\triangle S$$
$$\triangle G = +25 - 300 \times (\tfrac{-50}{1000})$$
$$= +25 - 300 \times (-0.05)$$
$$= +25 - (-15)$$
$$= +25 + 15$$
$$\triangle G = +40$$

$\Rightarrow \Delta G$ is positive, the reaction is non-spontaneous.

(C) $\Delta H = -22\,kJ/mol, \Delta S = +50\,J/mol$

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

$\triangle G = -22 - 300 \times (\frac{50}{1000})$

$= -22 - 300 \times (0.05)$

$= -22 - (15)$

$\triangle G = -37$

$\Rightarrow \Delta G$ is negative, the reaction is spontaneous.

(D) $\Delta H = -22\,kJ/mol, \Delta S = 80\,J/mol$

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

$\triangle G = -22 - 300 \times (\frac{80}{1000})$

$= -22 - 300 \times (0.08)$

$= -22 - 24$

$\triangle G = -46$

$\Rightarrow \Delta G$ is negative, the reaction is spontaneous.

So, The Correct answer is only option (B) $\Delta H = +25kJ/mol, \Delta S = -50J/mol$.

Concepts:

1. Laws of Thermodynamics:

Thermodynamics in physics is a branch that deals with heat, work and temperature, and their relation to energy, radiation and physical properties of matter.

The First Law of Thermodynamics:

The first law of thermodynamics, also known as the Law of Conservation of Energy, states that energy can neither be created nor destroyed; energy can only be transferred or changed from one form to another.

The Second Law of Thermodynamics:

The second law of thermodynamics says that the entropy of any isolated system always increases. Isolated systems spontaneously evolve towards thermal equilibrium—the state of maximum entropy of the system. More simply put: the entropy of the universe (the ultimate isolated system) only increases and never decreases.

The Third Law of Thermodynamics:

The third law of thermodynamics states that the entropy of a system approaches a constant value as the temperature approaches absolute zero. The entropy of a system at absolute zero is typically zero, and in all cases is determined only by the number of different ground states it has. Specifically, the entropy of a pure crystalline substance (perfect order) at absolute zero temperature is zero

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8. Answer: a

Explanation:

Correct answer is (a): A is correct but R is not correct
$2C(s) + O_2(g) \rightarrow 2CO(g)$
$\Delta_r S^0$ is $+ve, \Delta_r G^0 = \Delta_r H^0 - T\Delta_r S^0$; thus slope is negative
As temperature increases $\Delta_r G^0$ becomes more negative thus it has lower tendency to get decomposed.

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Explanation:

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

$Ink = \frac{n \times F \times E^\circ}{R \times T} = \frac{2 \times 96000 \times 2}{8 \times 300}$

Ink = 160

$k = e^{160}$

Concepts:

1. Equilibrium Constant:

The equilibrium constant may be defined as the ratio between the product of the molar concentrations of the products to that of the product of the molar concentrations of the reactants with each concentration term raised to a power equal to the stoichiometric coefficient in the balanced chemical reaction.

The equilibrium constant at a given temperature is the ratio of the rate constant of forwarding and backward reactions.

Equilibrium Constant Formula:

Kequ = kf/kb = [C]c [D]d/[A]a [B]b = Kc

where Kc, indicates the equilibrium constant measured in moles per litre.

For reactions involving gases: The equilibrium constant formula, in terms of partial pressure will be:

Kequ = kf/kb = [[pC]c [pD]d]/[[pA]a [pB]b] = Kp

Where Kp indicates the equilibrium constant formula in terms of partial pressures.

- Larger Kc/Kp values indicate higher product formation and higher percentage conversion.
- Lower Kc/Kp values indicate lower product formation and lower percentage conversion.

Medium Kc/Kp values indicate optimum product formation.

Units of Equilibrium Constant:

The equilibrium constant is the ratio of the concentrations raised to the stoichiometric coefficients. Therefore, the **unit of the equilibrium constant = [Mole L-1]Δn.**

where, Δn = sum of stoichiometric coefficients of products – a sum of stoichiometric coefficients of reactants.

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10. **Answer: c**

Explanation:

$TV^{\gamma-1} = \text{Constant}\ T_f = 300\left(\frac{V}{2V}\right)^{\frac{5}{3}-1} = 189\,,K\ \ \Delta U = nC_v\Delta T = 2 \times \frac{3R}{2} \times [189-300] = -2.7\,kJ$

Concepts:

1. Internal Energy:

Internal Energy is the microscopic energy contained within a system formed by the disordered movement of molecules (kinetic energy), Potential energy, and the nuclear energy present within the atoms of these molecules. It should be noted that the kinetic energy of molecules present in the system and not the kinetic energy of the system is calculated in the Internal Energy.

The Internal Energy is denoted by 'U' and is measured in Joules (J). This Internal Energy can increase with the increase in temperature and change of state or phase (from solid to liquid to gas). Heat Reservoirs store this Internal Energy.

Different Substances will have different Internal Energies depending on the atom, temperature, bonds, pressure, etc.

Forms of Internal Energy:

There are two forms of Internal Energy namely Kinetic Energy and Potential Energy

- **Kinetic Energy:** Kinetic Energy is the energy produced by the particles due to their motion. The motion of particles can be Rotational, Translational, Vibrational, etc., and hence the energies from these movements will be Translational Energies, Vibrational Energies, Rotational Energies, etc.
- **Potential Energy:** Potential Energy can be achieved from different types of interaction between particles, nuclear energy, electronic energy, etc.