Chemical Thermodynamics JEE Main PYQ - 3

Total Time: 1 Hour : 15 Minute **Total Marks:** 120

Instructions

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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.

Thermodynamics

1. **When Ethane-1,2-diamine is added progressively to an aqueous solution of Nickel (II) chloride, the sequence of colour change observed will be:** (+4, -1)

   a. Green → Pale Blue → Blue → Violet

   b. Pale Blue → Blue → Green → Violet

   c. Pale Blue → Blue → Violet → Green

   d. Violet → Blue → Pale Blue → Green

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2. **Which of the following mixing of 1M base and 1M acid leads to the largest increase in temperature?** (+4, -1)

   a. 30 mL CH_3COOH and 30 mL NaOH

   b. 45 mL CH_3COOH and 25 mL NaOH

   c. 50 mL HCl and 20 mL NaOH

   d. 30 mL HCl and 30 mL NaOH

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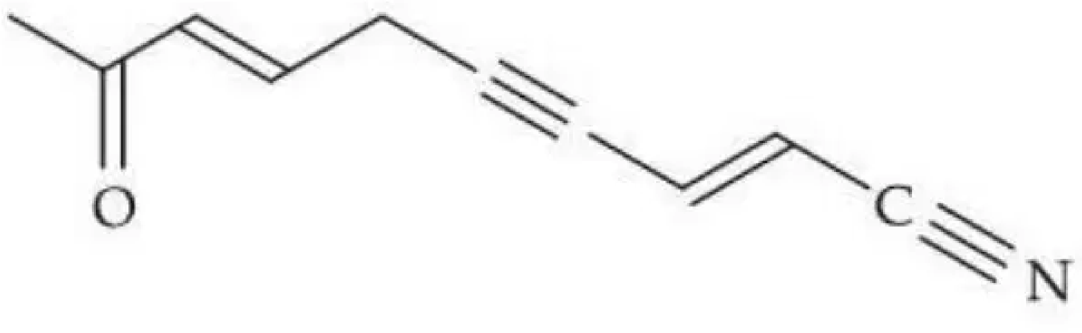
3. **In the given structure, number of sp and sp^2 hybridized carbon atoms present respectively are:** (+4, -1)



   a. 3 and 5

   b. 4 and 5

c. 3 and 6

d. 4 and 6

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4. **500 J of energy is transferred as heat to 0.5 mol of Argon gas at 298 K and 1.00 atm. The final temperature and the change in internal energy respectively are:** Given $R = 8.3\,JK^{-1}\,mol^{-1}$ **Choose the correct answer from the options given below:** **(+4, -1)**

a. 348 K and 300 J

b. 378 K and 500 J

c. 378 K and 300 J

d. 368 K and 500 J

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5. **Choose the correct statements.** **(+4, -1)**
(A) Weight of a substance is the amount of matter present in it.
(B) Mass is the force exerted by gravity on an object.
(C) Volume is the amount of space occupied by a substance.
(D) Temperatures below 0°**C are possible in Celsius scale, but in Kelvin scale negative temperature is not possible.**
(E) Precision refers to the closeness of various measurements for the same quantity.
Choose the correct answer from the options given below:

a. (A), (B) and (C) Only

b. (B), (C) and (D) Only

c. (C), (D) and (E) Only

d. (A), (D) and (E) Only

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6. **The correct option with order of melting points of the pairs (Mn, Fe), (Tc, Ru) and (Re, Os) is:** **(+4, -1)**

a. $Fe < Mn,\ Ru < Tc\ and\ Re < Os$

b. $Mn < Fe,\ Tc < Ru\ and\ Os < Re$

c. $Mn < Fe,\ Tc < Ru\ and\ Re < Os$

d. $Fe < Mn,\ Ru < Tc\ and\ Os < Re$

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7. The reaction $A_2 + B_2 \rightarrow 2AB$ follows the mechanism: **(+4, -1)**

$$A_2 \xrightarrow{k_1} A + A\,(fast) \quad A + B_2 \xrightarrow{k_2} AB + B\,(slow) \quad A + B \rightarrow AB\,(fast)$$

The overall order of the reaction is:

a. 3

b. 1.5

c. 2.5

d. 2

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8. 1.24 g of AX_2 (molar mass 124 g mol^{-1}) is dissolved in 1 kg of water to form a solution with boiling point of 100.105°C, while 2.54 g of AY_2 (molar mass 250 g mol^{-1}) in 2 kg of water constitutes a solution with a boiling point of 100.026°C. $K_{b(H_2O)} = 0.52\,\mathrm{K\ kg\ mol^{-1}}$. Which of the following is correct? **(+4, -1)**

a. AX_2 and AY_2 (both) are fully ionised.

b. AX_2 is fully ionised while AY_2 is completely unionised.

c. AX_2 and AY_2 (both) are completely unionised.

d. AX_2 is completely unionised while AY_2 is fully ionised.

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9. Match List - I with List - II: List - I: (A) Amylase **(+4, -1)**
(B) Cellulose
(C) Glycogen
(D) Amylopectin

List - II: (I) β-C1-C4 plant
(II) α-C1-C4 animal
(III) α-C1-C4 α-C1-C6 plant
(IV) α-C1-C4 plant
Choose the correct answer from the options given below:

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

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

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

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

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10. The standard reduction potential values of some of the p-block ions are given below. Predict the one with the strongest oxidising capacity. **(+4, -1)**

a. $E^\circ\, I_3^-/I_2 = +1.26\, V$

b. $E^\circ\, Al^{3+}/Al = -1.66\, V$

c. $E^\circ\, Pb^{4+}/Pb^{2+} = +1.67\, V$

d. $E^\circ\, Sn^{4+}/Sn^{2+} = +1.15\, V$

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11. For a given reaction $R \to P$, $t_{1/2}$ is related to $[A_0]$ as given in the table. Given: $\log 2 = 0.30$**. Which of the following is true?** **(+4, -1)**

[A] (mol/L)	$t_{1/2}$ (min)
0.100	200
0.025	100

a. A. The order of the reaction is $\frac{1}{2}$.

b. B. If $[A_0]$ is 1 M, then $t_{1/2}$ is $200/\sqrt{10}$ min.

c. C. The order of the reaction changes to 1 if the concentration of reactant changes from 0.100 M to 0.500 M.

d. D. $t_{1/2}$ is 800 min for $[A_0] = 1.6$ M.

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12. Ice and water are placed in a closed container at a pressure of 1 atm and temperature 273.15K. If pressure of the system is increased 2 times, keeping temperature constant, then identify correct observation from the following: **(+4, -1)**

a. Volume of system increases.

b. The amount of ice decreases.

c. Liquid phase disappears completely.

d. The solid phase (ice) disappears completely.

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13. What is the freezing point depression constant of a solvent, 50 g of which contain 1 g non-volatile solute (molar mass 256 g mol^{-1}) and the decrease in freezing point is 0.40 K? **(+4, -1)**

a. 5.12 K kg mol^{-1}

b. 4.43 K kg mol^{-1}

c. 1.86 K kg mol^{-1}

d. 3.72 K kg mol^{-1}

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14. The incorrect decreasing order of atomic radii is: **(+4, -1)**

a. Mg>Al>C>O

b. Al>B>N>F

c. Be>Mg>Al>Si

d. Si>P>Cl>F

15. **Consider 'n' as the number of lone pairs of electrons present in the equatorial position of the most stable structure of $\mathrm{ClF_3}$. The ions from the following with 'n' number of unpaired electrons are:** **(+4, -1)**

A. $\mathrm{V^{3+}}$

B. $\mathrm{Ti^{3+}}$

C. $\mathrm{Cu^{2+}}$

D. $\mathrm{Ni^{2+}}$

E. $\mathrm{Ti^{2+}}$

Choose the correct answer from the options given below:

a. B and D Only

b. B and C Only

c. A, D and E Only

d. A and C Only

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16. **The molecules having square pyramidal geometry are:** **(+4, -1)**

a. $\mathrm{BrF_5}$ & $\mathrm{XeOF_4}$

b. $\mathrm{SbF_5}$ & $\mathrm{XeOF_4}$

c. $\mathrm{BrF_5}$ & $\mathrm{PCl_5}$

d. $\mathrm{SbF_5}$ & $\mathrm{PCl_5}$

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17. **A weak acid HA has degree of dissociation x. Which option gives the correct expression of $pH - pK_a$?** **(+4, -1)**

a. $\log(1 + 2x)$

b. 0

c. $\log\left(\frac{x}{1-x}\right)$

d. $\log\left(\frac{1-x}{x}\right)$

18. For a certain reaction at 300 K, $K = 10$, then ΔG° for the same reaction is **(+4, -1)**

$$-\_ \times 10^{-1}\,\mathrm{kJ\ mol^{-1}}.$$

(Given $R = 8.314\,\mathrm{JK^{-1}mol^{-1}}$)

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19. For the reaction at $298\,\mathrm{K}$, $2\mathrm{A} + \mathrm{B} \rightarrow \mathrm{C}$. $\Delta H = 400\,\mathrm{kJ\ mol^{-1}}$ and $\Delta S = 0.2\,\mathrm{kJ\ mol^{-1}\,K^{-1}}$. The reaction will become spontaneous above ____ K. **(+4, -1)**

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20. Combustion of 1 mole of benzene is expressed as $C_6H_6(l) + \frac{15}{2}O_2(g) \rightarrow 6CO_2(g) + 3H_2O(l)$. The standard enthalpy of combustion of 2 mol of benzene is x kJ. x = __________ **(+4, -1)**

(1) standard Enthalpy of formation of 1 mol of $C_6H_6(l)$, for the reaction $6C(\text{graphite}) + 3H_2(g) \rightarrow C_6H_6(l)$ is 48.5 kJ $\mathrm{mol^{-1}}$.

(2) Standard Enthalpy of formation of 1 mol of $CO_2(g)$, for the reaction 6(graphite) + $O_2(g) \rightarrow CO_2(g)$ is -393.5 kJ $\mathrm{mol^{-1}}$.

(3) Standard Enthalpy of formation of 1 mol of $H_2O(l)$, for the reaction $H_2(g) + \frac{1}{2} O_2(g) \rightarrow H_2O(l)$ is -286 kJ $\mathrm{mol^{-1}}$.

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21. Three moles of an ideal gas are compressed isothermally from 60 L to 20 L using constant pressure of 5 atm. Heat exchange Q for the compression is – ____ Lit. atm. **(+4, -1)**

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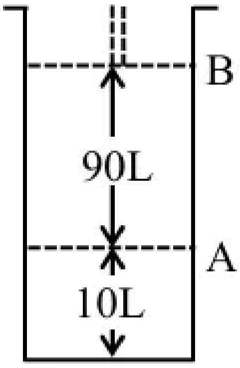
22. **(+4, -1)**



Consider the figure provided. 1 mol of an ideal gas is kept in a cylinder, fitted with a piston, at the position A, at $18^\circ\mathrm{C}$. If the piston is moved to position B, keeping the temperature unchanged, then 'x' $\mathrm{L\ atm}$ work is done in this reversible process. $x =$ ______ $\mathrm{L\ atm.}$ (nearest integer)

[Given: Absolute temperature $=^\circ \mathrm{C} + 273.15$, $R = 0.08206\,\mathrm{L\ atm\ mol^{-1}K^{-1}}$]

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23. The heat of solution of anhydrous $CuSO_4$ and $CuSO_4{\cdot}5H_2O$ are -70 kJ $\mathrm{mol^{-1}}$ and $+12$ kJ $\mathrm{mol^{-1}}$ respectively. The heat of hydration of $CuSO_4$ to $CuSO_4{\cdot}5H_2O$ **(+4, -1)**

is $-x$ kJ. The value of x is _____.

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24. The heat of combustion of solid benzoic acid at constant volume is $-321.30\,\text{kJ}$ at $27°\text{C}$. The heat of combustion at constant pressure is $(-321.30 - xR)\,\text{kJ}$. The value of x is: **(+4, -1)**

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

Assertion (A): Enthalpy of neutralisation of strong monobasic acid with strong monoacidic base is always –57 kJ mol^{-1}

Reason (R): Enthalpy of neutralisation is the amount of heat liberated when one mole of H^+ ions furnished by acid combine with one mole of ^-OH ions furnished by base to form one mole of water. In the light of the above statements.

Choose the correct answer from the options given below.

a. (A) is true but (R) is false

b. Both (A) and (R) are true and (R) is the correct explanation of (A)

c. (A) is false but (R) is true

d. Both (A) and (R) are true but (R) is not the correct explanation of (A)

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26. The enthalpy of formation of ethane (C_2H_6) from ethylene by addition of hydrogen, **(+4, -1)**

where the bond energies of $C-H$, $C-C$, $H-H$ are $414\,\text{kJ}$, $347\,\text{kJ}$, $615\,\text{kJ}$, and $435\,\text{kJ}$ respectively, is __________ kJ.

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27. If 5 moles of an ideal gas expands from $10\,L$ to a volume of $100\,L$ at $300\,K$ under isothermal and reversible conditions, then work, w, is $-x\,J$. The value of x is ______. **(+4, -1)**

(Given $R = 8.314\,\text{J K}^{-1}\text{mol}^{-1}$)

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28. When $\Delta H_{\text{vap}} = 30\,\text{kJ/mol}$ and $\Delta S_{\text{vap}} = 75\,\text{J mol}^{-1}\text{K}^{-1}$, then the temperature of vapour, at one atmosphere, is .... K. **(+4, -1)**

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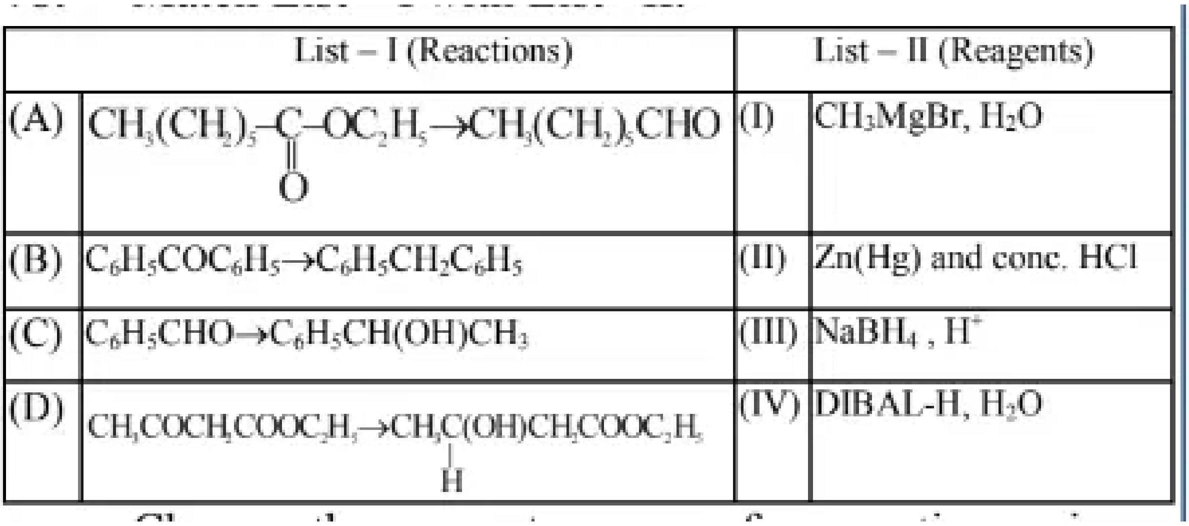
29. Consider the following reaction at 298 K. **(+4, -1)**

$\frac{3}{2}O_{2(g)} \rightleftharpoons O_{3(g)}, K_p = 2.47 \times 10^{-29}$.

$\Delta_r G^{\theta}$ for the reaction is ______ kJ. (Given R=$8.314\ JK^{-1}mol^{-1}$)

30. Match List – I with List –II. **(+4, -1)**



List – I (Reactions)		List – II (Reagents)	
(A)	$CH_3(CH_2)_5-\underset{\underset{O}{\|}}{C}-OC_2H_5 \rightarrow CH_3(CH_2)_5CHO$	(I)	CH_3MgBr, H_2O
(B)	$C_6H_5COC_6H_5 \rightarrow C_6H_5CH_2C_6H_5$	(II)	Zn(Hg) and conc. HCl
(C)	$C_6H_5CHO \rightarrow C_6H_5CH(OH)CH_3$	(III)	$NaBH_4$, H^+
(D)	$CH_3COCH_2COOC_2H_5 \rightarrow CH_3\underset{\underset{H}{\|}}{C}(OH)CH_2COOC_2H_5$	(IV)	DIBAL-H, H_2O

Choose the correct answer from options given below:

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

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

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

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

Answers

1. **Answer: c**

Explanation:

- As ethane-1,2-diamine is added to the solution, the nickel (II) complex undergoes changes in coordination, resulting in a series of color transitions. Initially, the solution is pale blue and then turns blue, followed by violet, and finally green. **Final Answer:** Option (3).

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2. **Answer: c**

Explanation:

- The heat generated in an acid-base neutralization reaction is proportional to the amount of acid and base mixed, which is the product of the molarities and volumes. - The combination that results in the largest heat release will have the highest product of molarities and volumes. - When comparing the options, the mix of 50 mL of HCl and 20 mL of NaOH will have the highest heat increase since it involves a strong acid and a strong base, leading to the largest amount of heat generated. **Final Answer:** Option (3).

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3. **Answer: a**

Explanation:

- The structure contains sp and sp^2 hybridized carbon atoms. - The carbon atoms in triple bonds (i.e., the C≡N bond) are sp-hybridized. - The carbon atoms in the C=C double bonds and in the C=O group are sp^2-hybridized. - Thus, the number of sp-hybridized atoms is 3 and the number of sp^2-hybridized atoms is 5. **Final Answer:** Option (1).

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4. **Answer: c**

Explanation:

We can use the formula for the heat absorbed by the gas:

$$Q = nC_V\Delta T$$

Where: - $Q = 500\,J$ (heat transferred), - $n = 0.5\,mol$, - $C_V = 3R/2$ (molar heat capacity for a monoatomic gas, where $R = 8.3\,J/mol\cdot K$). First, calculate C_V:

$$C_V = \frac{3}{2} \times 8.3 = 12.45\,J/mol\cdot K$$

Now, solve for the temperature change ΔT:

$$500 = 0.5 \times 12.45 \times \Delta T$$

$$\Delta T = \frac{500}{0.5 \times 12.45} = 80\,K$$

The final temperature:

$$T_f = 298\,K + 80\,K = 378\,K$$

The change in internal energy is $\Delta U = 300\,J$. Thus, the correct answer is (3) 378 K and 300 J.

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5. Answer: c

Explanation:

- (A) is incorrect. Weight is the force exerted by gravity on an object, not the amount of matter.
- (B) is incorrect. Mass is the amount of matter, not the force due to gravity.
- (C) is correct. Volume is indeed the amount of space occupied by a substance.
- (D) is correct. Temperatures below 0°C are possible in Celsius scale, but negative temperatures are not possible in the Kelvin scale. - (E) is correct. Precision refers to the closeness of repeated measurements. Thus, the correct answer is (3) (C), (D) and (E) Only.

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6. Answer: c

Explanation:

- The melting point of Mn is lower than Fe because Mn has a lower atomic number and a less stable crystal structure compared to Fe.
- The melting point of Tc is lower than Ru due to the differences in atomic structure and bonding.
- The melting point of Re is lower than Os because Os has a higher atomic number and stronger metallic bonding, leading to a higher melting point. Thus, the correct answer is $Mn < Fe,\ Tc < Ru\ and\ Re < Os$.

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7. Answer: b

Explanation:

The overall rate law is determined by the slow step of the mechanism, which is:

$$Rate = k_2[A][B_2]$$

Since the fast step $A_2 \rightarrow A + A$ is equilibrium, we can use the equilibrium constant k_1 to express $[A]$ in terms of $[A_2]$:

$$[A] = \sqrt{k_1[A_2]}$$

Substituting this into the rate law:

$$Rate = k_2\sqrt{k_1[A_2]}[B_2]$$

Thus, the overall rate law is:

$$Rate = k[A_2]^{1/2}[B_2]^1$$

The overall order of the reaction is $1/2 + 1 = 1.5$.

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8. Answer: a

Explanation:

To find the correct answer, we use the formula for the elevation in boiling point, which is given by:

$$\Delta T_b = K_b \times m \times i$$

where ΔT_b is the boiling point elevation, K_b is the ebullioscopic constant, m is the molality, and i is the van't Hoff factor (which gives the number of particles the compound dissociates into). Since we are given the boiling point changes, we can compare the values of i (the ionisation factor) for each compound. The change in boiling point is given as:

$$\Delta T_b = T_{solution} - T_{solvent} = 100.105°C - 100.000°C = 0.105°C$$

For AX$_2$:

$$m = \frac{1.24\,g}{124\,g/mol \times 1\,kg H_2O} = \frac{1.24}{124} \approx 0.01\,mol/kg$$

Using the formula for ΔT_b:

$$0.105 = 0.52 \times 0.01 \times i$$

Solving for i, we get:

$$i = \frac{0.105}{0.52 \times 0.01} \approx 2$$

Thus, AX$_2$ is fully ionised (since $i = 2$). For AY$_2$:

$$m = \frac{2.54\,g}{250\,g/mol \times 2\,kg H_2O} = \frac{2.54}{250 \times 2} \approx 0.005\,mol/kg$$

Using the same formula for ΔT_b:

$$0.026 = 0.52 \times 0.005 \times i$$

Solving for i, we get:

$$i = \frac{0.026}{0.52 \times 0.005} \approx 1$$

Thus, AY$_2$ is also fully ionised (since $i = 1$). Hence, the correct answer is that both AX$_2$ and AY$_2$ are fully ionised.

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9. Answer: b

Explanation:

- Amylase: This is a polysaccharide found in plants, with α-1,4 and α-1,6 linkages between glucose units, so the correct linkage type is α-C1-C4 plant (IV).
- Cellulose: Cellulose is a polysaccharide made of β-1,4 linkages, commonly found in plants, so the correct linkage is β-C1-C4 plant (I).
- Glycogen: Glycogen is a polysaccharide found in animals, consisting of α-1,4 and α-1,6 linkages between glucose units, so the correct linkage is α-C1-C4 α-C1-C6 plant (III).
- Amylopectin: Similar to glycogen, it is found in plants and is made of α-1,4 and α-1,6 linkages, so the correct linkage is α-C1-C4 plant (II). Thus, the correct answer is (2).

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10. Answer: c

Explanation:

The strength of an oxidising agent is directly related to its reduction potential. The higher the reduction potential, the stronger the oxidising agent. Among the options, the highest reduction potential is for Pb^{4+}/Pb^{2+}, with a value of $+1.67\,V$. Thus, the strongest oxidising agent is Pb^{4+}.

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11. Answer: a

Explanation:

Step 1: From the given data, calculate the order of the reaction. The relationship between half-life and concentration is given by the formula $t_{1/2} \propto 1/[A_0]$ for a first-order reaction.

Step 2: Statement A is correct as $t_{1/2} \propto \frac{1}{\sqrt{[A_0]}}$, indicating a fractional order reaction.

Step 3: Statement B is correct because the half-life depends on the initial concentration.

Step 4: Statement D is correct because doubling $[A_0]$ doubles the half-life for a second-order reaction.

Final Conclusion: The correct answer is Option (1), A, B and D Only.

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12. **Answer: b**

Explanation:

Increasing the pressure at constant temperature will push the equilibrium towards the liquid phase (since the solid phase occupies less volume). As a result, the amount of ice decreases. Final Conclusion: The correct answer is Option (2), the amount of ice decreases.

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13. **Answer: c**

Explanation:

The freezing point depression ΔT_f is given by:

$$\Delta T_f = K_f \times m$$

where K_f is the freezing point depression constant, and m is the molality.

Step 1: First, calculate the molality m:

$$m = \frac{\text{mol of solute}}{\text{kg of solvent}} = \frac{\frac{1}{256}}{\frac{50}{1000}} = \frac{1}{256} \times \frac{1000}{50} = 0.078125\,\text{mol/kg}$$

Step 2: Using the formula for freezing point depression:

$$\Delta T_f = K_f \times m$$

Substitute $\Delta T_f = 0.40\,\text{K}$ and $m = 0.078125\,\text{mol/kg}$:

$$0.40 = K_f \times 0.078125$$

$$K_f = \frac{0.40}{0.078125} = 1.86\,\text{K kg mol}^{-1}$$

Final Conclusion: The freezing point depression constant is 1.86 K kg mol^{-1}, which corresponds to Option (3).

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14. **Answer: c**

Explanation:

The atomic radius decreases across a period from left to right due to the increase in effective nuclear charge, but increases down a group due to the addition of electron shells.

Step 1: $\mathrm{Be} > \mathrm{Mg} > \mathrm{Al} > \mathrm{Si}$ is incorrect because atomic radius decreases as we move from Be to Si.

Final Conclusion: The incorrect order is Option (3), $\mathrm{Be} > \mathrm{Mg} > \mathrm{Al} > \mathrm{Si}$

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15. Answer: a

Explanation:

The unpaired electrons depend on the electronic configuration of the ions. The number of unpaired electrons in Ti^{3+} and Ni^{2+} ions will match the given condition for n. Final Conclusion: The correct answer is Option (1), B and D Only.

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16. Answer: a

Explanation:

BrF$_5$ and XeOF$_4$ both have square pyramidal structures based on VSEPR theory. BrF$_5$ has 5 bonding pairs and 1 lone pair, while XeOF$_4$ has 4 bonding pairs and 1 lone pair on the central xenon atom, forming a square pyramidal shape.

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17. Answer: a

Explanation:

The Henderson-Hasselbalch equation for a weak acid is $pH = pK_a + \log\left(\frac{[A^-]}{[HA]}\right)$. Given the dissociation degree x, the expression becomes $pH = pK_a + \log(1 + 2x)$, assuming the weak acid dissociates into x molar concentration of H$^+$ and A$^-$ while undissociated HA remains $1 - x$.

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18. Answer: 57 - 57

Explanation:

Given:

We are asked to calculate ΔG° using the formula:

$$\Delta G^{\circ} = -RT \ln K$$

Step 1: Substituting the known values into the equation:

Given that $R = 8.314\,\mathrm{J/molK}$, $T = 300\,\mathrm{K}$, and $K = 10$, we substitute these values into the equation:

$$\Delta G^{\circ} = -8.314 \times 300 \ln(10)$$

Step 2: Simplifying the equation:

Calculating the logarithm of 10:

$$\Delta G^{\circ} = -8.314 \times 300 \times 2.3026$$

This simplifies to:

$$\Delta G^{\circ} = -5744.14\,\mathrm{J/mol}$$

Step 3: Converting to kJ/mol:

To express the result in kJ/mol, divide by 1000:

$$\Delta G^{\circ} = -5.744\,\mathrm{kJ/mol} \quad \Rightarrow \quad \Delta G^{\circ} = 57.44 \times 10^{-1}\,\mathrm{kJ/mol}$$

Final Answer:

The correct answer is $57\,\mathrm{kJ/mol}$.

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19. Answer: 2000 - 2000

Explanation:

The problem asks for the temperature above which the given reaction becomes spontaneous. We are provided with the standard enthalpy change (ΔH) and standard entropy change (ΔS) for the reaction at 298 K.

Concept Used:

The spontaneity of a reaction is determined by the sign of the Gibbs free energy change (ΔG). The relationship between ΔG, enthalpy change (ΔH), and entropy change (ΔS) at a constant temperature T is given by the Gibbs-Helmholtz equation:

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

For a reaction to be spontaneous, the value of ΔG must be negative $(\Delta G < 0)$. The transition from a non-spontaneous to a spontaneous process occurs at the temperature where the system is at equilibrium, which is defined by the condition $\Delta G = 0$. This temperature is known as the equilibrium temperature, T_{eq}.

Step-by-Step Solution:

Step 1: Write down the given thermodynamic values for the reaction.

$$\Delta H = 400\,\text{kJ mol}^{-1}$$

$$\Delta S = 0.2\,\text{kJ K}^{-1}\text{mol}^{-1}$$

Note that the units are consistent (both are in kJ).

Step 2: Determine the condition for the reaction to become spontaneous.

The reaction becomes spontaneous when $\Delta G < 0$.

$$\Delta H - T\Delta S < 0$$

The threshold temperature for this change is the equilibrium temperature (T_{eq}), where $\Delta G = 0$.

Step 3: Set $\Delta G = 0$ in the Gibbs-Helmholtz equation to find the equilibrium temperature.

$$0 = \Delta H - T_{eq}\Delta S$$

Rearranging the equation to solve for T_{eq}:

$$T_{eq}\Delta S = \Delta H$$

$$T_{eq} = \frac{\Delta H}{\Delta S}$$

Step 4: Substitute the given values of ΔH and ΔS into the equation to calculate T_{eq}.

$$T_{eq} = \frac{400\,\text{kJ mol}^{-1}}{0.2\,\text{kJ K}^{-1}\text{mol}^{-1}}$$

Final Computation & Result:

Performing the calculation for the equilibrium temperature:

$$T_{eq} = 2000\,\text{K}$$

This is the temperature at which the reaction is at equilibrium. Since both ΔH (enthalpy) and ΔS (entropy) are positive, the reaction is endothermic and becomes more disordered. For the reaction to be spontaneous ($\Delta G < 0$), the entropy term ($T\Delta S$) must be larger than the enthalpy term (ΔH). This occurs at temperatures above the equilibrium temperature.

Therefore, the condition for spontaneity is $T > T_{eq}$.

The reaction will become spontaneous above **2000 K**.

---

20. Answer: 6535 - 6535

Explanation:

The enthalpy change for the combustion reaction can be calculated using Hess's law:

$$\Delta H = \sum \Delta H_f(\text{products}) - \sum \Delta H_f(\text{reactants}).$$

Step 1: Write the given reaction
The reaction for 1 mole of benzene is:

$$\text{C}_6\text{H}_6(l) + \frac{15}{2}\text{O}_2(g) \rightarrow 6\text{CO}_2(g) + 3\text{H}_2\text{O}(l).$$

Step 2: Calculate the enthalpy change for 1 mole of benzene
Using the standard enthalpies of formation:

$$\Delta H_f(\mathrm{CO_2}(g)) = -393.5\,\mathrm{kJ/mol},$$

$$\Delta H_f(\mathrm{H_2O}(l)) = -286\,\mathrm{kJ/mol},$$

$$\Delta H_f(\mathrm{C_6H_6}(l)) = 48.5\,\mathrm{kJ/mol}.$$

For the products:

$$\Delta H_f(\text{products}) = [6 \times (-393.5)] + [3 \times (-286)].$$

$$\Delta H_f(\text{products}) = -2361 - 858 = -3219\,\mathrm{kJ/mol}.$$

For the reactants:

$$\Delta H_f(\text{reactants}) = [1 \times 48.5] + \left(\frac{15}{2} \times 0\right).$$

$$\Delta H_f(\text{reactants}) = 48.5\,\mathrm{kJ/mol}.$$

The enthalpy change for the combustion of 1 mole of benzene is:

$$\Delta H = \Delta H_f(\text{products}) - \Delta H_f(\text{reactants}),$$

$$\Delta H = -3219 - 48.5 = -3267.5\,\mathrm{kJ/mol}.$$

Step 3: Calculate for 2 moles of benzene
For 2 moles of benzene:

$$\Delta H = 2 \times (-3267.5) = -6535\,\mathrm{kJ}.$$

Final Answer: $x = 6535\,\text{kJ}$.

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21. Answer: 200 - 200

Explanation:

As isothermal $U = 0$ and the process is irreversible:

$$Q = -W = -\left[-P_{\text{ext}}(V_2 - V_1)\right]$$

$$Q = 5 \times (20 - 60) = -200\,\text{atm-L}$$

Given:

$$P_{\text{ext}} = 5\,\text{atm}, \quad V_1 = 60\,\text{L}, \quad V_2 = 20\,\text{L}$$

Substituting the values:

$$Q = 5 \times (20 - 60) = -200\,\text{atm-L}$$

Thus, the heat exchange for the compression is $200\,\text{Lit. atm}$.

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22. Answer: 55 - 55

Explanation:

The work done by the gas in a reversible isothermal process can be calculated using the formula:
$W = nRT \ln\left(\frac{V_f}{V_i}\right)$
Where:

- W is the work done.
- $n = 1\,\text{mol}$ (amount of gas).

- $R = 0.08206\,\text{L atm mol}^{-1}\text{K}^{-1}$ (universal gas constant).
- T is the absolute temperature in Kelvin.
  Given $T = 18^\circ\text{C} + 273.15 = 291.15\,\text{K}$.
- $V_i = 10\,\text{L}$ (initial volume).
- $V_f = 100\,\text{L}$ (final volume).

Substitute the values into the formula:
$W = 1 \times 0.08206 \times 291.15 \times \ln\left(\frac{100}{10}\right)$
$W = 23.89989 \times \ln(10)$
$\ln(10) = 2.302$ (approx.)
$W \approx 23.89989 \times 2.302 \approx 55.028$
To the nearest integer, $W = 55\,\text{L atm}$.
This value falls within the expected range of 55, verifying its correctness.

---

23. Answer: 82 - 82

Explanation:

To find the heat of hydration $-x$ for the reaction where anhydrous $CuSO_4$ becomes $CuSO_4{\cdot}5H_2O$, we need to consider the heats of solution provided for each compound.

The problem provides:

Anhydrous $CuSO_4$: Heat of solution = $-70\,\text{kJ/mol}$

$CuSO_4{\cdot}5H_2O$: Heat of solution = $+12\,\text{kJ/mol}$

The heat of hydration is the energy change when $CuSO_4$ is hydrated to form $CuSO_4{\cdot}5H_2O$.

Considering the reactions:

(1) $\text{CuSO}_4\ (\text{anhydrous}) + \text{solvent} \rightarrow \text{solution}$ \quad $\Delta H_1 = -70\,\text{kJ/mol}$

(2) $\text{CuSO}_4 \cdot 5\text{H}_2\text{O} + \text{solvent} \rightarrow \text{solution}$ \quad $\Delta H_2 = +12\,\text{kJ/mol}$

The heat of hydration involves the transition from $CuSO_4$ to $CuSO_4{\cdot}5H_2O$:

$$\text{CuSO}_4 + 5\text{H}_2\text{O} \rightarrow \text{CuSO}_4 \cdot 5\text{H}_2\text{O}$$

This can be understood using Hess's law, which states the total enthalpy change for a reaction is the sum of the steps:

$\Delta H_{\text{hydration}} = \Delta H_2 - \Delta H_1$

Substitute the given enthalpy values:

$-x = 12\ \text{kJ/mol} - (-70\ \text{kJ/mol})$

$-x = 12\ \text{kJ/mol} + 70\ \text{kJ/mol}$

$-x = 82\ \text{kJ/mol}$

Thus, $x = 82\ \text{kJ/mol}$.

This value fits exactly within the given range of 82, 82.

Therefore, the heat of hydration is $x = 82$ kJ mol^{-1}.

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24. Answer: 150 - 150

Explanation:

The relation between heat at constant pressure (ΔH) and at constant volume (ΔU) is:

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

For benzoic acid:

$$C_6H_5COOH(s) + \frac{15}{2}O_2(g) \rightarrow 7CO_2(g) + 3H_2O(l)$$

$\Delta n_g = 7 - \frac{15}{2} = -\frac{1}{2}$. Substituting:

$$\Delta H = -321.30 - \frac{1}{2}R \times 300$$

Here, $R \approx 8.314\,\text{J/mol.K}$. Solving gives:

$$x = 150$$

---

25. Answer: b

Explanation:

Enthalpy of neutralisation of a strong acid (SA) and strong base (SB) is always -57 kJ/mol because a strong monoacid gives one mole of H^+ and a strong mono-base gives one mole of OH^-, which combine to form one mole of water. Both the assertion and reason are true, and (R) correctly explains (A).

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26. Answer: 125 - 125

Explanation:

Given Information:

Bond energies:

- $\text{C–H} = 414\,\text{kJ/mol}$
- $\text{C–C} = 347\,\text{kJ/mol}$
- $\text{H–H} = 435\,\text{kJ/mol}$
- $\text{C=C (double bond)} = 615\,\text{kJ/mol}$

Reaction for Formation of Ethane from Ethylene:

The reaction can be represented as:

$$\mathrm{C_2H_4}(g) + \mathrm{H_2}(g) \to \mathrm{C_2H_6}(g)$$

Bond Energy Calculations:

Breaking Bonds:

- One C=C bond in ethylene: $615\,\text{kJ}$
- One H–H bond: $435\,\text{kJ}$
- Total energy required to break bonds = $615 + 435 = 1050\,\text{kJ}$

Forming Bonds:

- One C–C bond in ethane: $347\,\text{kJ}$
- Two C–H bonds: $2 \times 414 = 828\,\text{kJ}$
- Total energy released in forming bonds = $347 + 828 = 1175\,\text{kJ}$

Enthalpy Change (ΔH):

$$\Delta H = \text{Energy required to break bonds} - \text{Energy released in forming bonds}$$

$$\Delta H = 1175 - 1050 = 125\,\text{kJ}$$

Conclusion:

The enthalpy of formation of ethane from ethylene by addition of hydrogen is $125\,\text{kJ}$.

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27. Answer: 28721 - 28721

Explanation:

To calculate the work done on an ideal gas during isothermal, reversible expansion, we use the formula:
$w = -nRT\ln\left(\frac{V_f}{V_i}\right)$, where:

$n = 5$ moles,
$R = 8.314\,\text{J K}^{-1}\text{mol}^{-1}$,
$T = 300\,\text{K}$,
$V_i = 10\,\text{L}$,
$V_f = 100\,\text{L}$.

Substitute the values into the equation:

$w = -5 \times 8.314 \times 300\ln\left(\frac{100}{10}\right)$

Calculate the natural logarithm:

$\ln(10) \approx 2.302$

Calculate the work:

$w = -5 \times 8.314 \times 300 \times 2.302$

$w \approx -28721\,\text{J}$

Thus, the value of x is 28721. This value fits perfectly within the provided range [28721, 28721].

---

28. Answer: 400 - 400

Explanation:

To find the temperature of vaporization at one atmosphere using the given enthalpy of vaporization (ΔH_{vap}) and entropy of vaporization (ΔS_{vap}), we apply the formula derived from the Gibbs free energy relation at equilibrium:

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

Solving for temperature (T), we get:

$$T = \frac{\Delta H_{\text{vap}}}{\Delta S_{\text{vap}}}$$

Convert $\Delta H_{\text{vap}} = 30\ \text{kJ/mol}$ to joules:

$$30\ \text{kJ/mol} = 30,000\ \text{J/mol}$$

Then, substitute the values into the formula:

$$T = \frac{30,000\ \text{J/mol}}{75\ \text{J mol}^{-1}\text{K}^{-1}} = 400\ \text{K}$$

The temperature is calculated to be 400 K, which fits within the provided range of 400,400. Therefore, the temperature of vaporization at one atmosphere is confirmed to be 400 K.

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29. Answer: 163 - 163

Explanation:

Given Reaction:

The reaction is as follows:

$$\frac{3}{2}O_2(g) \rightleftharpoons O_3(g), \quad K_p = 2.47 \times 10^{-29}$$

Calculation of $\Delta_r G^\circ$:

The formula to calculate the standard Gibbs free energy change $\Delta_r G^\circ$ is:

$$\Delta_r G^\circ = -RT \ln K_p$$

Substitute the known values:

$$\Delta_r G^\circ = -(8.314 \times 10^{-3}\,\text{kJ/mol/K}) \times 298\,\text{K} \times \ln(2.47 \times 10^{29})$$

Now calculate the value of $\ln(2.47 \times 10^{29})$:

$$\ln(2.47 \times 10^{29}) = -65.87$$

Substitute this back into the equation:

$$\Delta_r G^\circ = -(8.314 \times 10^{-3} \times 298 \times -65.87) = 163.19\,\text{kJ}$$

Conclusion:

The standard Gibbs free energy change is $\Delta_r G^\circ = 163.19\,\text{kJ}$.

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30. Answer: a

Explanation:

$$\mathrm{CH_3(CH_2)_5COOC_2H_5 \xrightarrow{\text{DIBAL-H, } H_2O} CH_3(CH_2)_5CHO}$$

$$\mathrm{C_6H_5COC_6H_5 \xrightarrow{Zn(Hg)\ \&\ \text{conc. } HCl} C_6H_5CH_2C_6H_5}$$

$$\mathrm{C_6H_5 \xrightarrow{CH_3MgBr,\ H_2O} C_6H_5CH(OH)CH_3}$$

$$\mathrm{CH_3COCH_2COOC_2H_5 \xrightarrow{NaBH_4,H^+} CH_3CH(OH)CH_2COOC_2H_5}$$