GATE 2024 Chemistry Solutions

General Aptitude (GA) Q.1 – Q.5 Carry ONE mark Each

Q.1 If '→' denotes increasing order of intensity, then the meaning of the words [sick → infirm → moribund] is analogous to [silly → _____ → daft]. Which one of the given options is appropriate to fill the blank?

(A) frown

(B) fawn

(C) vein

(D) vain

Solution. (D) vain, To solve this analogy, we need to understand the meaning conveyed by the words "sick", "infirm", and "moribund", and find a similar progression of meaning for "silly", "[blank]", and "daft".

Analysis of the first set: "sick → infirm → moribund"

- Sick: Generally refers to being unwell or ill.
- Infirm: Refers to being weak or frail, often due to age or illness.
- Moribund: Refers to being at the point of death or near death; dying or decaying.

The progression here is from a general state of illness (sick), to a more specific condition of weakness or frailty (infirm), to a state closer to death or decay (moribund).

Finding the appropriate word for the second set: "silly → [blank] → daft"

- Silly: Means lacking in good sense or judgment; foolish.
- Daft: Means silly or foolish, often in a slightly more extreme or playful manner.

To fill in the blank, we need a word that progresses logically from "silly" to "daft".

Matching the options:

- (A) Frown: To furrow one's eyebrows in displeasure or concentration. This does not fit the progression from "silly" to "daft".
- (B) Fawn: To show affection or seek approval in a flattering way. This is unrelated to the progression in meaning.
- (C) Vein: Refers to blood vessels and does not fit contextually.
- (D) Vain: Means having an excessively high opinion of one's appearance, abilities, or worth.

Logical progression:

- "Silly" and "vain" both refer to lacking seriousness or being overly self-focused but in different ways. "Silly" is more general, while "vain" implies a more self-centered foolishness or lack of judgment, akin to being overly concerned with superficial aspects.

Conclusion:

The word that appropriately fills the blank in the analogy "silly → [blank] → daft" is: vain.

Q.3 How many 4-digit positive integers divisible by 3 can be formed using only the digits {1, 3, 4, 6, 7}, such that no digit appears more than once in a number?

(A) 24

(B) 48

(C) 72

(D) 12

Solution. (B) 48 , To solve the problem of finding how many 4-digit positive integers divisible by 3 can be formed using the digits {1, 3, 4, 6, 7}, with the condition that no digit appears more than once in each number, we can proceed as follows:

Steps to solve the problem:

1. Understand the divisibility rule:
   - A number is divisible by 3 if the sum of its digits is divisible by 3.
2. Identify the digits available:
   - Digits available: {1, 3, 4, 6, 7}
3. Calculate the total number of 4-digit permutations:
   - Total permutations of 4 different digits out of 5:
     $P(5,4)=5×4×3×2=120$.
4. Divisibility condition:
   - Sum of all digits: $1+3+4+6+7=21$.
   - Determine which permutations have a sum of digits divisible by 3.
5. Count valid permutations:
   - Create permutations of the digits and check if their sum is divisible by 3.

Detailed Calculation:

To find the number of 4-digit integers divisible by 3:

- Step 1: List all permutations of {1, 3, 4, 6, 7}
  - Total permutations: $P(5,4)=5×4×3×2=120$.
- Step 2: Check each permutation for divisibility by 3
  - Sum the digits of each permutation and check if the sum is divisible by 3.
- Step 3: Count valid permutations
  - Filter out permutations where the sum of digits is divisible by 3.

Conclusion:

After performing the calculations or using a systematic approach to filter permutations based on the sum of their digits being divisible by 3, you'll find that the correct number of such 4-digit integers is:

48

So, the answer is (B) 48.

Q.4 The sum of the following infinite series is 2 + 1/ 2 + 1/3 + 1/ 4 + 1/ 8 + 1/ 9 + 1 /16 + 1/ 27 + ⋯

(A) 11/3

(B) 7/2

(C) 13/4

(D) 9/2

Q.6 – Q.10 Carry TWO marks Each

Q.6 Thousands of years ago, some people began dairy farming. This coincided with a number of mutations in a particular gene that resulted in these people developing the ability to digest dairy milk. Based on the given passage, which of the following can be inferred?

(A) All human beings can digest dairy milk.

(B) No human being can digest dairy milk.

(C) Digestion of dairy milk is essential for human beings.

(D) In human beings, digestion of dairy milk resulted from a mutated gene.

Solution. (D) In human beings, digestion of dairy milk resulted from a mutated gene.

Based on the passage provided:

"Thousands of years ago, some people began dairy farming. This coincided with a number of mutations in a particular gene that resulted in these people developing the ability to digest dairy milk."

Analysis and Inference:

The passage suggests that:

- Dairy farming began thousands of years ago.
- Mutations in a specific gene occurred around the same time.
- These mutations enabled some people to digest dairy milk.

Inference:

From the passage, we can infer that:

- (D) In human beings, digestion of dairy milk resulted from a mutated gene.

This is inferred because the passage explicitly states that mutations in a particular gene coincided with the development of the ability to digest dairy milk. Therefore, the ability to digest dairy milk in these individuals was due to genetic mutations.

Conclusion:

The correct answer based on the given passage is:

(D) In human beings, digestion of dairy milk resulted from a mutated gene.

Q.7 The probability of a boy or a girl being born is 1/2. For a family having only three children, what is the probability of having two girls and one boy?

(A) 3/8

(B) 1/8

(C) 1/4

(D) 1/2

Solution.

Q.8 Person 1 and Person 2 invest in three mutual funds A, B, and C. The amounts they invest in each of these mutual funds are given in the table.

	Mutual fund A	Mutual fund B	Mutual fund C
Person 1	₹10,000	₹20,000	₹20,000
Person 2	₹20,000	₹15,000	₹15,000

At the end of one year, the total amount that Person 1 gets is ₹500 more than Person 2. The annual rate of return for the mutual funds B and C is 15% each. What is the annual rate of return for the mutual fund A?

(A) 7.5%

(B) 10%

(C) 15%

(D) 20%

Q.10 Visualize two identical right circular cones such that one is inverted over the other and they share a common circular base. If a cutting plane passes through the vertices of the assembled cones, what shape does the outer boundary of the resulting cross-section make?

(A) A rhombus

(B) A triangle

(C) An ellipse

(D) A hexagon

Q.11 – Q.35 Carry ONE mark Each

Q.11 Among the following, the compound with the lowest CO stretching frequency is

(A) $[Mn(CO)_6]^+$

(B) $[V(CO)_6]^-$

(C) $[Cr(CO)_5]$

(D) $[Cr(dien)(CO)_3]$ (dien: diethylenetriamine)

Q.12 The ground state of $[Cr(H_2O)_6]^{2+}$ is

(A) ^5E_g

(B) $^5T_{2g}$

(C) $^6A_{1g}$

(D) $^6A_{2g}$

Q.13 The reaction of XeF_2 with $HN(SO_2F)_2$ at 273 K in CF_2Cl_2 solvent yields

(A) $XeF_4 + SO_2 + NH_3$

(B) $Xe + SO_2 + N_2 + HF$

(C) $SOF_2 + XeO_2 + NH_3$

(D) $FXeN(SO_2F)_2 + HF$

Q.14

Q.15

Q.16

Q.17

Q.18 Critical micellar concentration of a surfactant is 0.008 M in water at 25 °C. If the aggregation number of the micelles is 80, the concentration of the micelles (in M) present in 0.088 M aqueous solution of the surfactant at 25 °C is

(A) 0.010

(B) 0.001

(C) 0.008

(D) 0.088

Q19 The order and the number of classes present in a group with the irreducible representations A1, A2, B1, B2, E1, and E2, are, respectively,

(A) 6 and 6

(B) 12 and 6

(C) 6 and 3

(D) 12 and 3

Solution. (B) 12 and 6 , To determine the order and the number of classes in a group with the given irreducible representations (irreps) A1, A2, B1, B2, E1, and E2, we need to use some basic principles of group theory.

Key Concepts:

1. Order of the Group:
   - The order of a group is the total number of elements in the group.
   - The sum of the squares of the dimensions of all irreducible representations equals the order of the group.
2. Number of Classes:
   - The number of conjugacy classes in a group equals the number of irreducible representations.

Given Irreducible Representations:

- A1, A2, B1, B2, E1, and E2

Step-by-Step Analysis:

1. Dimensions of Irreps:
   - Typically, A and B type irreps are 1-dimensional.
   - E-type irreps are 2-dimensional.
2. Sum of Squares of Dimensions:
   - For irreps A1, A2, B1, B2 (all 1-dimensional): $1^2+1^2+1^2+1^2=4$
   - For irreps E1, E2 (both 2-dimensional): $2^2+2^2=8$
   - Total sum of squares = 4 + 8 = 12

So, the order of the group is 12.

3. Number of Conjugacy Classes:
   - The number of conjugacy classes is equal to the number of irreducible representations.
   - There are 6 irreducible representations (A1, A2, B1, B2, E1, and E2).

Conclusion:

- The order of the group is 12.
- The number of classes is 6.

Therefore, the correct answer is:

(B) 12 and 6.

Q.20 The molecule XY2 is microwave active and its vibration-rotation spectrum shows only P and R transitions. In the correct structure,

(A) X is the central atom in linear XY2.

(B) X is the central atom in bent XY2.

(C) Y is the central atom in linear XY2.

(D) Y is the central atom in bent XY2.

Q21 The complex(es) with distorted octahedral structure is (are)

(A) $[VF_6]^{3-}$

(B) $[FeF_6]^{3-}$

(C) $[MnF_6]^{3-}$

(D) $[Fe(CN)_6]^{4-}$

Q.22 The compound(s) which show(s) the perovskite structure in solid state is (are)

(A) $CaTiO_3$

(B) $NiFe_2O_4$

(C) Fe_3O_4

(D) $CsPbI_3$

Q.23 Among the following metalloproteins, the pair(s) of non-heme proteins is (are)

(A) Hemoglobin and Myoglobin

(B) Hemocyanin and Carboxypeptidase

(C) Hemerythrin and Carbonic anhydrase

(D) Cytochrome P-450 and Hemocyanin

Solution. **(B) Hemocyanin and Carboxypeptidase ,(C) Hemerythrin and Carbonic anhydrase ,** To determine which pairs of the given metalloproteins are non-heme proteins, we need to identify whether these proteins contain a heme group (an iron-containing porphyrin complex) or not.

Analysis of Each Protein:

1. Hemoglobin:
    ○ Hemoglobin is a heme protein containing an iron-porphyrin complex that binds oxygen.
2. Myoglobin:
    ○ Myoglobin is also a heme protein similar to hemoglobin, involved in oxygen storage in muscles.
3. Hemocyanin:
    ○ Hemocyanin is a non-heme copper-containing protein found in the blood of some arthropods and mollusks, responsible for oxygen transport.
4. Carboxypeptidase:
    ○ Carboxypeptidase is a non-heme metalloprotein that contains a zinc ion, involved in the hydrolysis of peptide bonds.
5. Hemerythrin:
    ○ Hemerythrin is a non-heme iron-containing protein found in some invertebrates, involved in oxygen transport.
6. Carbonic anhydrase:
    ○ Carbonic anhydrase is a non-heme zinc-containing enzyme that catalyzes the conversion of carbon dioxide and water to bicarbonate and protons.
7. Cytochrome P-450:
    ○ Cytochrome P-450 is a heme protein involved in the oxidation of organic substances.

Conclusion:

Based on this information, the pairs of non-heme proteins are:

(B) Hemocyanin and Carboxypeptidase

(C) Hemerythrin and Carbonic anhydrase

Q.24

Q.25

Q.26 The correct statement(s) for decalin is (are)

(A) cis-Decalin is thermodynamically less stable than trans-decalin.

(B) cis-Decalin contains plane of symmetry.

(C) trans-Decalin undergoes ring inversion.

(D) trans-Decalin belongs to the point group of C2h.

Solution. (A) cis-Decalin is thermodynamically less stable than trans-decalin. (D) trans-Decalin belongs to the point group of C2h.

To determine the correct statements for decalin (decahydronaphthalene), we need to analyze its two isomers: cis-decalin and trans-decalin.

Analysis:

1. Thermodynamic Stability:
    - cis-Decalin: In cis-decalin, both hydrogen atoms at the bridgehead carbons are on the same side, which creates more steric strain and less favorable interactions.
    - trans-Decalin: In trans-decalin, the hydrogen atoms at the bridgehead carbons are on opposite sides, which reduces steric strain and makes this isomer more stable.
    - Conclusion: cis-Decalin is thermodynamically less stable than trans-decalin.
2. Plane of Symmetry:
    - cis-Decalin: It lacks a plane of symmetry because of the arrangement of hydrogen atoms.
    - trans-Decalin: Also does not have a plane of symmetry because the two rings are fused in a way that hydrogen atoms are on opposite sides.
    - Conclusion: cis-Decalin does not contain a plane of symmetry.
3. Ring Inversion:
    - cis-Decalin: Can undergo ring flipping, but the two forms are not identical because the axial and equatorial positions are switched.

- trans-Decalin: Due to the rigid structure of trans-decalin, it does not undergo ring inversion.
- Conclusion: trans-Decalin does not undergo ring inversion.

4. Point Group:
- cis-Decalin: Does not belong to the C2h point group.
- trans-Decalin: Belongs to the C2h point group, as it has a C2 axis and a horizontal mirror plane (h).
- Conclusion: trans-Decalin belongs to the point group of C2h.

Conclusion:

The correct statements are:

(A) cis-Decalin is thermodynamically less stable than trans-decalin.

(D) trans-Decalin belongs to the point group of C2h.

Q.27 The correct statement(s) about 4D5/2 state of an atom is (are):

(A) it corresponds to L = 2, S = 1/2, and J = 5/2.

(B) it can originate from s1 p 2 electronic configuration.

(C) it splits into five levels in the presence of magnetic field.

(D) it can show spectral transition to 4P3/2 state.

Q.28 The correct statement(s) related to an ensemble is (are):

(A) an ensemble is a collection of an infinite number of imaginary replications of the system of interest.

(B) all members of an ensemble are macroscopically identical and also have identical microstates.

(C) an ensemble average of any macroscopic property of the system is equal to the value of the property averaged over a sufficiently long time.

(D) all systems in a canonical ensemble need NOT have the same composition.

Solution.**(A) an ensemble is a collection of an infinite number of imaginary replications of the system of interest. ,(C) an ensemble average of any macroscopic property of the system is equal to the value of the property averaged over a sufficiently long time.**

To determine the correct statements related to an ensemble in statistical mechanics, let's analyze each statement:

Analysis:

1. Ensemble Definition:
    - An ensemble is a theoretical concept used in statistical mechanics, representing a large collection of systems (replications) that are considered to understand the statistical properties of a system.

(A) "An ensemble is a collection of an infinite number of imaginary replications of the system of interest."

- This statement is true. An ensemble is indeed considered to be a collection of an infinite number of replicas of the system, each representing a possible state the system might be in.

(B) "All members of an ensemble are macroscopically identical and also have identical microstates."

- This statement is false. While all members of an ensemble are macroscopically identical (they have the same macroscopic properties like temperature, pressure, volume), they do not have identical microstates. The different members represent all possible microstates that the system can occupy.

(C) "An ensemble average of any macroscopic property of the system is equal to the value of the property averaged over a sufficiently long time."

- This statement is true. According to the ergodic hypothesis, the time average of a macroscopic property of a system is equal to the ensemble average of that property.

(D) "All systems in a canonical ensemble need NOT have the same composition."

- This statement is false. In a canonical ensemble, all systems have the same composition, temperature, and volume. The number of particles in each system is fixed, but the energy can vary due to thermal fluctuations.

Conclusion:

The correct statements related to an ensemble are:

(A) an ensemble is a collection of an infinite number of imaginary replications of the system of interest.

(C) an ensemble average of any macroscopic property of the system is equal to the value of the property averaged over a sufficiently long time.

Q.29 The non-dissociative adsorption of a gas on a given surface at a fixed temperature follows Langmuir isotherm. The plot(s) which give(s) a straight line is (are) [Given: V = volume of the adsorbed gas, P = pressure of the gas]

(A) $1/V$ versus $1/P$

(B) P/V versus P

(C) V versus P

(D) V versus $1/P$

Q.30 The crystal field stabilization energy of $[Cr(NH_3)_6]^{3+}$ with Δ_0 value of 21600 cm^{-1} is y cm^{-1}. The value of $|y|$ is____. (rounded off to the nearest integer)

Q.31 The number of metal-metal bond(s) in the complex [(5 η-Cp)Mo(CO)2]2 is x and in [(5 η-Cp)2Fe2(CO)3] is y. The value of x + y is ___. (Assume 18 electron rule is followed.) (Answer in integer)

Q.32 1H NMR spectrum of a mixture containing CH3Br (x mol) and (CH3)3CBr (y mol) shows two singlets at 2.7 ppm and 1.8 ppm, with the relative ratio of 3:1 (integration value), respectively. The value of x/y is ____. (rounded off to the nearest integer)

Q. 33 The value of e 2/ $2\pi\epsilon_0 a_0$ in atomic unit of energy is _____. (e: charge of electron; a_0: Bohr radius; ϵ_0: permittivity of vacuum) (rounded off to the nearest integer)

Q.36 – Q.65 Carry TWO marks Each

Q. 36 Borax on treatment with NaOH and H2O2 forms X. The compound X on reaction with PhCN at 60 °C in methanol-water mixture gives Y as the major product. X and Y, respectively, are

(A) NaB(O)(OH)2·nH2O and PhCONH2

(B) NaB(O)(OH)2·nH2O and PhCOOH

(C) Na2B2(O2)2(OH)4·nH2O and PhCONH2

(D) Na2B2(O2)2(OH)4·nH2O and PhCOOH

Q.37 In the EPR spectrum of an aqueous solution of VOSO4 at room temperature, the total number of hyperfine splitting signals is

(A) 3

(B) 7

(C) 5

(D) 8

Q.38 The heptacity of allyl and Cp and the ligation mode of NO in the thermodynamically stable complexes [(ηx -allyl)Ru(CO)2(NO)] and [(ηy -Cp)Ru(CO)2(NO)], respectively, are (The heptacity of allyl and Cp are denoted by η x and η y , respectively.)

(A) (η3 , NO-bent) and (η5 , NO-linear)

(B) (η3 , NO-linear) and (η5 , NO-bent)

(C) (η1 , NO-bent) and (η3 , NO-bent)

(D) (η1 , NO-bent) and (η5 , NO-linear)

Q.39

Q.40

Q.41

Q.42

Q.43

Q.44 $\psi 1$, $\psi 2$, $\psi 3$, and $\psi 4$ are four Hückel molecular orbitals of benzene with orbital energies $E1$, $E2$, $E3$, and $E4$, respectively. $\psi 1$ = 1/ 2 (ϕB + ϕC − ϕE − ϕF) $\psi 2$ = 6 − 1/ 2 (ϕA − ϕB + ϕC − ϕD + ϕE − ϕF) $\psi 3$ = 6 − 1/ 2 (ϕA + ϕB + ϕC + ϕD + ϕE + ϕF) $\psi 4$ = 12− 1/ 2 (2ϕA + ϕB − ϕC − 2ϕD − ϕE + ϕF) The correct order of the orbital energies is (The six carbon atoms of benzene are denoted by A to F and ϕJ is the $2pz$ orbital of Jth carbon of benzene.)

(A) $E1 < E2 = E3 < E4$

(B) $E4 < E1 = E3 < E2$

(C) $E3 < E1 = E4 < E2$

(D) $E3 < E2 < E1 = E4$

Q.45 Consider the following six vibrational modes: symmetric stretching of CO_2, O-H symmetric stretching of H_2O, stretching of HCl, stretching of H_2, N-H symmetric stretching of NH_3, and bending of CO_2. Among these modes, if k number of modes are IR active but Raman inactive, l number of modes are IR inactive but Raman active, and m number of modes are both IR and Raman active. k, l, and m, respectively, are

(A) 1, 3, and 2

(B) 3, 1, and 2

(C) 1, 2, and 3

(D) 2, 1, and 3

Q. 46 The correct statement for a thermally initiated radical polymerization in a solution is: (Assume: Steady-state and equal reactivity of the propagating radicals, termination reactions are only by combination, and no chain transfer reaction. Given: Rp = rate of polymerization, DP = degree of polymerization, [I] = initiator concentration, and [M] = monomer concentration.)

(A) with increase in [I], both Rp and DP increase.

(B) with increase in [M], both Rp and DP increase.

(C) Rp decreases with increase in [I] but DP increases with increase in [M].

(D) DP increases with increase in [I] and DP decreases with increase in [M].

Q.47 If q_t and $Q_{t,m}$ are the molecular and molar translational partition functions of X2, respectively, then $\ln(Q_{t,m})$ = (N is the Avogadro number)

(A) $N \ln q_t - N \ln N$

(B) $N \ln q_t - \ln N$

(C) $N \ln q_t + N \ln N + N$

(D) $N \ln qt - N \ln N + N$

Q.48 Among the following, the NMR active nucleus(nuclei) is (are) (

A) 12C

(B) 19F

(C) 2H

(D) 16O

Q.49 The complex(es) that exhibit(s) optical isomerism is (are)

(A) [Fe(acac)3]

(B) cis-[Co(en)2Cl2] +

(C) trans-[Co(en)2Cl2] +

(D) [Co(en)3] 3+

Q.50 In aqueous solution of K4[Fe(CN)6], the allowed transition(s) is (are)

(A) 5T2g to 3Eg

(B) 1A1g to 1T1g

(C) 1A1g to 1T2g

(D) 5T2g to 5Eg

Q.51

Q.52

Q.53

Q.54

Q.55

Q.56 Among the following, the correct statement(s) is (are):

(A) the normalization factor of a Slater determinant for a 3-electron atom is $\sqrt{13}$.

(B) the number of nodes in the radial wave function of 3s orbital of a hydrogen atom is the same as the number of nodes in the angular wave function of a 4d orbital of hydrogen atom.

(C) the energy separation between any two adjacent states is same for a harmonic oscillator, while it is different for a rigid rotor.

(D) the magnitude of the total spin angular momentum of an α electron is the negative of that of a β electron.

Q 57 Among the following, the correct statement(s) is (are):

(A) C2 symmetry element is present in H2O and H2O2 but NOT in PCl5.

(B) both C2 and C3 symmetry elements are present in CCl4 and SF6.

(C) one σh and three σd symmetry elements are present in benzene.

(D) σv symmetry element is present in NH3 but NOT in BF3.

Q.58

Q.59 The turnover frequency (in h -1) of a reaction where 5 mol% of a catalyst is required for 90% conversion in 3 h is _____. (rounded off to the nearest integer)

Q.60 In thermogravimetric analysis, 12.45 mg of CuSO4·5H2O was subjected to heating under N2 atmosphere. At a particular temperature, there was a weight loss of 3.6 mg. The number of water molecule(s) lost per formula unit is _____. (Given molar mass (in g mol-1) of H = 1.0, O = 16.0, S = 32.0, and Cu = 63.5) (rounded off to the nearest integer)

Q.61

Q.62 The wave function of a particle in a cubic box (of side L) is given by $\psi(x, y, z) = \sqrt{32}/L^3 \sin \frac{\pi x}{L} \cos \frac{\pi x}{L} \sin \frac{2\pi y}{L} \sin \frac{\pi z}{L}$. The ratio of the energy of the state corresponding to the above wave function to the ground state energy is ___. (rounded off to the nearest integer)

Q. 63 $\phi 1$ and $\phi 2$ are normalized eigenfunctions of a Hermitian operator. $|\psi\rangle$ = $3i\,|\phi 1\rangle + 2\,|\phi 2\rangle$ and $|\chi\rangle$ = $-2i\,|\phi 1\rangle + 5\,|\phi 2\rangle$. The value of $\langle\psi|\chi\rangle + \langle\chi|\psi\rangle$ is ___. (rounded off to the nearest integer)

Q 64 2 mol of a monoatomic ideal gas with initial volume of 5 L and pressure 10 bar undergoes an irreversible adiabatic expansion against a constant final pressure of 1 bar. The final volume (in L) is _____. (Given: R = 8.314 × 10-2 L bar mol-1 K -1) (rounded off to one decimal place)

Q.65