GS-2020 (Chemistry)

Full Name :

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Roll No. :

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TATA INSTITUTE OF FUNDAMENTAL RESEARCH

Written Test in **CHEMISTRY**

December 8th, 2019

Duration: Three hours (3 hours)

Please read all instructions carefully before you attempt the questions.

1. Write your FULL NAME and ROLL NUMBER (see hall ticket) in block letters, both on this page and on your answer sheet (at the end of this booklet).
2. This is a multiple-choice question paper with **ONE** section having a total of 40 questions. Each correct answer will get you 3 marks. Every wrong answer will get you -1 mark. Marks are not awarded or deducted when a question is not attempted. It is better not to answer a question if you are not sure.
3. Indicate your answers on the ANSWER SHEET by filling completely in the appropriate boxes. Do not mark more than one box for any question; this will be treated as an incorrect answer.
4. We advise you to first mark the correct answers in the QUESTION SHEET, and later transfer them to the ANSWER SHEET only when you are sure of your choice.
5. Rough work may be done on the back of the QUESTION SHEET. If needed, you may ask for extra rough sheets from an invigilator.
6. In answering the questions, please choose the option that best describes the solution to the problem.
7. **Use of calculators is permitted in this subject test.**

SOME USEFUL DATA

Avogadro number = 6.02×10^{23} mol^{-1}
RT/F = 0.0257 V at 25°C
Faraday constant = 96500 C/mol
Boltzmann constant $k_B = 1.38\times10^{-23}$ J K^{-1}
Mass of an electron = 9.109×10^{-31} kg

e = 1.6×10^{-19} C
h = 6.626×10^{-34} J s
c = 3×10^{8} m s^{-1}
R = 8.314 J K^{-1} mol^{-1}

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1. Order of field effect of alkyl groups are tert-butyl > iso-propyl > ethyl > methyl. Which molecule among $PhCH_3$, $PhCH_2CH_3$, $PhCH(CH_3)_2$ and $PhC(CH_3)_3$ has the highest dipole moment in gas phase.

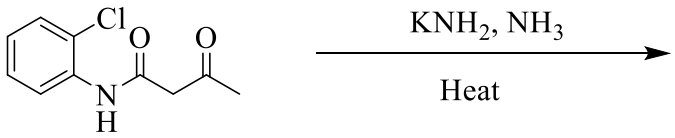
   A) $PhCH_3$

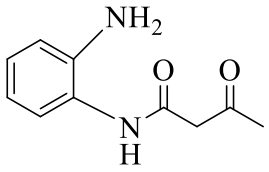
   B) $PhCH_2CH_3$

   C) $PhCH(CH_3)_2$

   D) $PhC(CH_3)_3$

2. Predict the product of the following reaction.



A)


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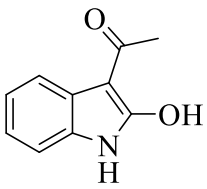

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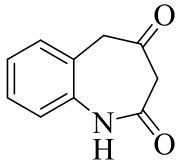
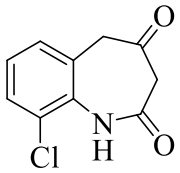
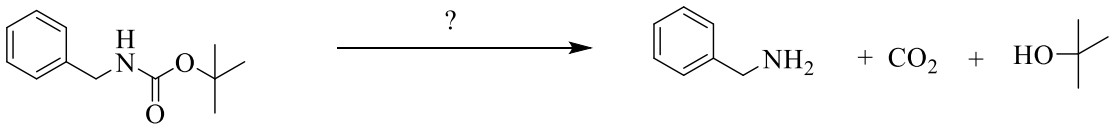


D)


Answer: B

3. Predict the reagent for the following amine de-protection reaction.



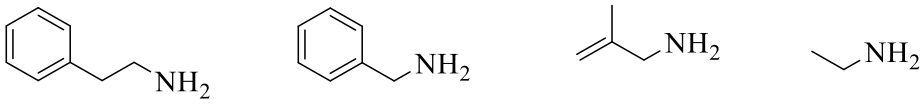
A) H_3O^+/H_2O

B) $NaOH/H_2O$

C) $NaCl/H_2O$

D) $Pd/C, H_2$

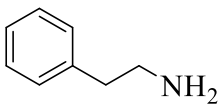
4. The octanol-water partition coefficient (Log *P*) for the following amines are as shown below:



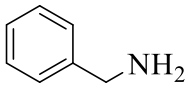
Log P	1.36	1.08	0.21	-0.32

Which amine will have the highest solubility in water?

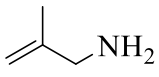
A)



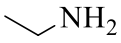
B)



C)



D)



Ans: D

5. A flask contains 1 litre of growth medium (in which E. coli. bacteria are grown) with 180 gm of glucose as the only Carbon source for the bacteria. Provide a rough estimate of the number of E. coli. that can grow upto the final stage given

    a. A bacterium contains ~ 3 x 10^6 protein molecules
    b. An average protein has ~300 amino acids
    c. Half of all glucose consumption goes to production

    A) 10^6

    B) 3 x 10^{14}

    C) 3 x 10^{16}

    D) 2.5 x 10^{13}

Answer: B

6. An optically transparent thin crystal shows a quadratic response to visible light, i.e. it scatters some of the light in a waveform that is square of the field of light that falls on it. If light of 500 nm wavelength falls on it, what are the wavelengths of the scattered light?

    A) 500 nm and 750 nm

    B) 500 nm and 250 nm

    C) 500 nm and 1000 nm

    D) 500 nm only

7. IR spectra of proteins have a peak in the 1600 – 1700 cm^{-1} region, known as the "Amide I" region. This comes largely from the backbone C=O stretch vibration. Given the natural abundance of different isotopes, would occasionally find a backbone C=O at a different frequency? If so, what would be the next most common frequency, assuming that the "Amide I" has a peak exactly at 1650 cm^{-1}?

    A) 1613 cm^{-1}

    B) 1693 cm^{-1}

    C) 1248 cm^{-1}

D) No other frequency will be observed

8. An ideal gas obeys the gas law PV= nRT. However, real gases deviate from this, and their behavior can be described in

   $PV/nRT = 1 + B_P P + \text{-----}$

   where B_P is the first virial coefficient in the expansion. Do you expect the B_P to be temperature dependent? If so, what would you expect the sign of B_P to be at low temperatures? (Near but above the critical point of condensation)

   A) B_P will be temperature independent

   B) Negative

   C) Positive

   D) Can be either positive or negative

9. In a spherical polar coordinate system, a point A at (x, y, z) in the Cartesian coordinate system can be described by (r, θ, ϕ) where r, θ, and ϕ have their usual meaning. Expression for the volume of an infinitesimally small cube confined by dx, dy, and dz in terms of the spherical coordinate system is given by

   A) $dr d\theta d\phi$

   B) $r\sin\theta dr d\theta d\phi$

   C) $r^2\sin^2\theta dr d\theta d\phi$

   D) $r^2\sin\theta dr d\theta d\phi$

10. The degeneracy of the energy level $12\ h^2/8\ ma^2$ of a particle in a three dimensional cube of length "a" is

    A) 1

    B) 3

    C) 6

    D) 12

11. Rotational energy of a diatomic molecule is given by $E_{rot} = J(J+1)hB_e$, where E_{rot} is in Joules. If the rotational constant for H_2 molecule is given as B_e = 1.8324 E+12 Hz, the rotational period of the H_2 molecule in J = 10 level will be

A) 1.33×10^{-19} sec

B) 5.0×10^{-15} sec

C) 5.46×10^{-13} sec

D) 7.39×10^{-7} sec

12. For a Harmonic Oscillator in its ground state, i.e., ν = 0 state, the energy is given by E= ½hν, where ν is the vibrational frequency. This is due to its

A) Kinetic energy

B) Potential energy

C) Sum of Kinetic and Potential energies

D) Heat of formation

13. The Standard reaction Gibbs energy (ΔG°) for the ATP hydrolysis

$ATP_{(aq)} \rightarrow ADP + P_{i(aq)}$ is -31 kJ/mol at 37°C.

In a typical bacterial cell, the concentration of ATP, ADP and P_i are 8 mmol L^{-1}, 1 mmol L^{-1} and 8 mmol L^{-1}, respectively. What is the reaction Gibbs energy under this condition?

A) -31 kJ mol^{-1}

B) -49 kJ mol^{-1}

C) -18 kJ mol^{-1}

D) -13 kJ mol^{-1}

14. The coefficient of compressibility of water at 293 K is 4.9×10^{-6} atm^{-1} in the range 1 to 25 atm pressure. What will be the value of work involving the compression of 1 mol of liquid water from a pressure of 1 atm to 25 atm at 293 K in a reversible process.

A) 21.75×10^{-5} atm dm^3

B) 0.2234×10^{-5} atm dm^3

C) 225.223×10^{-5} atm dm^3

D) 2.752×10^{-5} atm dm^3

15. For an ideal gas, $\left(\frac{\partial H}{\partial P}\right)_T$ is equal to

A) V

B) 0

C) $\left(\frac{\partial V}{\partial T}\right)_P$

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

16. The half-life for the decomposition of a substance dissolved in Chlorofom is 6 hours at 298K. How much of the substance will be left after a day if the initial weight of the dissolved substance is 160mg.

A) 40 mg

B) 160 mg

C) 10 mg

D) 27 mg

17. If 1.50 g of $H_2C_2O_4 \cdot 2H_2O$ were heated to drive off the water of hydration, how much anhydrous $H_2C_2O_4$ would remain?

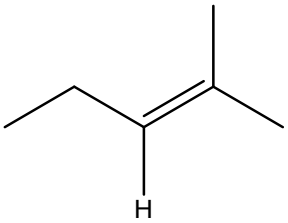
A) 0.34 g

B) 0.92 g

C) 1.07 g

D) 1.50 g

18. How many absorption peaks will the following compound have in its ^{13}C-NMR spectrum?



A) 3

B) 4

C) 5

D) 6

19. An organic compound is estimated through Dumas method and was found to evolve 6 moles of CO_2, 4 moles of H_2O and 1 mole of N_2 gas. The formula of the compound is:

A) $C_{12}H_8N$

B) $C_{12}H_8N_2$

C) C_6H_8N

D) $C_6H_8N_2$

20. Which of the following belongs to the same symmetry group as NH_3?

A) BF_3

B) CH_4

C) CH_3OH

D) $CHCl_3$

21. Within a circle of radius 'b', four largest possible identical circles of radius 'a' are fit such that they do not cross each other. What is the ratio a/b?

A) ½

B) 1/(1+sqrt(2))

C) 2/(1+sqrt(2))

D) 1/2(1+sqrt(2))

22. Beer's law for electromagnetic radiation absorption through a medium can be expressed as:

$I = I_0 \exp(-\alpha L)$

Where, α is the absorption coefficient, L is the path length through the medium, I_0 is the incident intensity and I is the transmitted intensity.

Consider an absorbing medium with two energy levels spaced by 600 cm^{-1}. On this medium, when monochromatic infrared radiation on resonance is made incident, which of the following statement(s) holds true?

A) Light absorption will increase with increasing the temperature of the absorbing medium

B) Beer's law is valid only for ultraviolet-visible part of the spectrum and is invalid in the infrared spectral region

C) Light absorption will decrease with increasing temperature of the absorbing medium

D) Light absorption not change with the temperature of the absorbing medium

23. In the case of Eigenstates of a particle in a box with infinite walls, which of the following statements is true about the wavefunction ($\psi(r)$), its first ($\psi'(r) = d\psi(r)/dr$) and second derivatives ($\psi''(r)= d^2\psi(r)/dr^2$)?

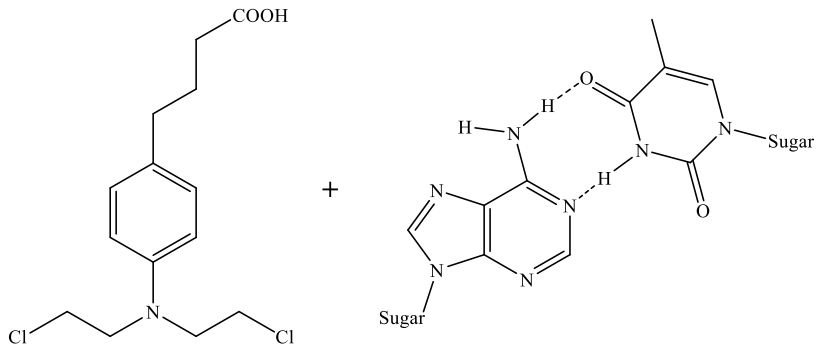
A) All three quantities are continuous everywhere

B) $\psi(r)$, $\psi'(r)$ are continuous but not $\psi''(r)$.

C) $\psi(r)$ is continuous everywhere, but discontinuous at the boundaries of the box.

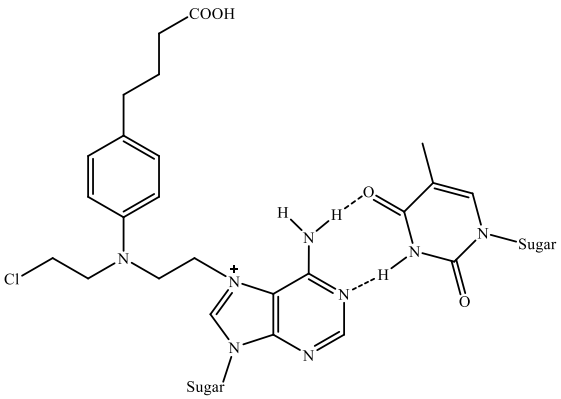
D) $\psi(r)$ is continuous everywhere, $\psi'(r)$ and $\psi''(r)$ are continuous everywhere except at the boundaries.

24. The nitrogen mustard Chlorambucil is an anti-cancer drug. Predict the product obtained when Chlorambucil interacts with the DNA base pair AT shown below under physiological conditions.

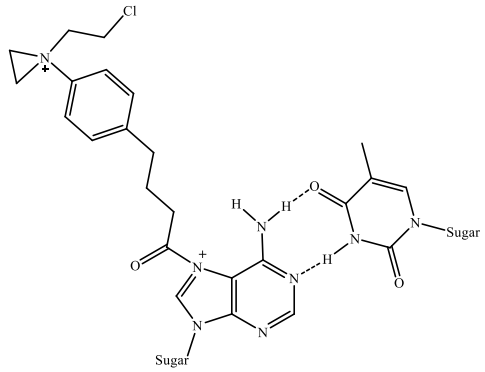


Chlorambucil

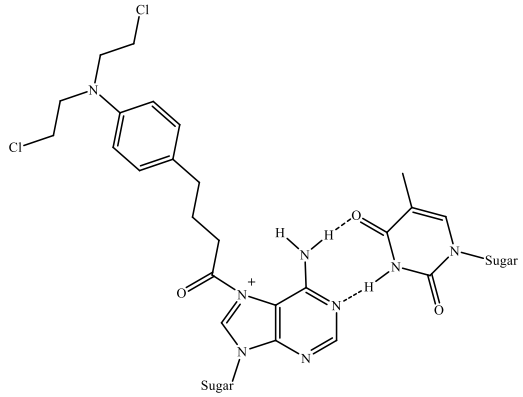
A)



B)


Cl
N
+
H
N
H
O
N
N
Sugar
O
+
N
H
N
O
N
N
Sugar

C)


Cl
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Cl
H
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H
O
N
N
Sugar
O
+
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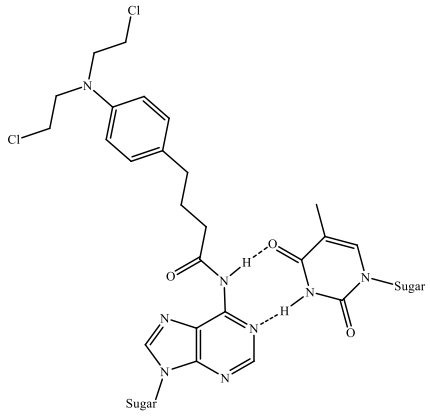
H
N
O
N
N
Sugar

D)


Cl
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Cl
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O
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N
Sugar
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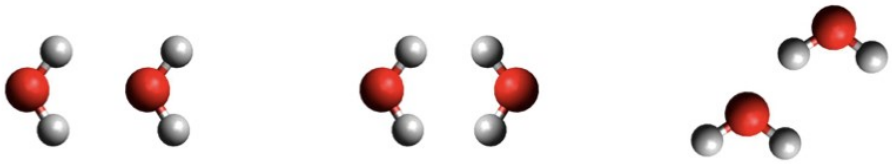
H
N
N
N
Sugar

25. An isolated water molecule has C_{2v} symmetry, however water clusters can have symmetries other than C_{2v}. What are the symmetries of the following three water clusters?



(i) (ii) (iii)

A) All of them have C_{2v} symmetry

B) i) C_{2v} ii) D_{2h} iii) C_s

C) i) C_s ii) D_{2h} iii) C_s

D) i) C_{2v} ii) D_{2h} iii) C_{2v}

26. Among the following, which molecule will have the smallest spacing between vibrational levels? (superscripts denote the nuclear mass of the atoms)

A) $^{1}H^{35}Cl$

B) $^{1}H^{37}Cl$

C) $^{2}H^{37}Cl$

D) $^{2}H^{35}Cl$

27. A complex of Chromium (3+) in aqueous hydrochloric acid, was found to exist in two geometric isomeric forms. A white precipitate was formed on addition of equimolar amount of $AgNO_3$ solution to the complex. The structure of the complex is:

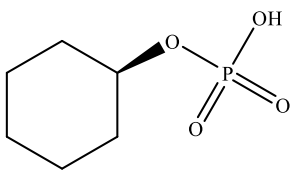
A) $[CrCl_3(H_2O)_3]$

B) $[CrCl_2(H_2O)_4]Cl$

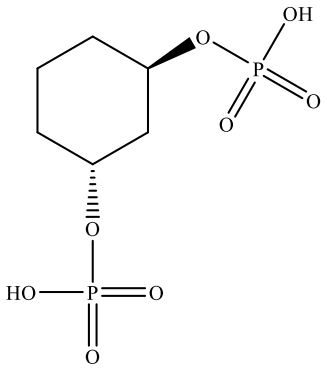
C) $[CrCl(H_2O)_5]Cl_2$

D) $[Cr(H_2O)_6]Cl_3$

28. Compound **2** and compound **1** were mixed in a 1:4 molar ratio. The mixture was subjected to an ammonium molybdate test for phosphate estimation. The result of the molybdate test yielded a phosphate concentration of 36.0 mM for the mixture. What are the concentrations of compound **1** and compound **2** in the mixture?



1



2

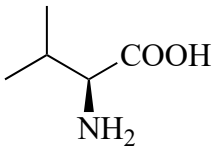
A) Compound **1**: 30 mM
Compound **2**: 6 mM

B) Compound **1**: 24 mM
Compound **2**: 6 mM

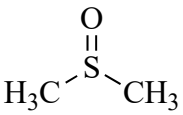
C) Compound **1**: 28.8 mM
Compound **2**: 7.2 mM

D) Compound **1**: 24 mM
Compound **2**: 12 mM

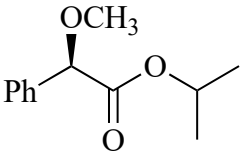
29. Methyl groups in the following compounds are



I



II



III

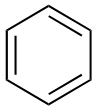
A) diastereotopic (**I**), enantiotopic (**II**), diastereotopic (**III**)

B) enantiotopic (**I**), enantiotopic (**II**), enantiotopic (**III**)

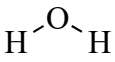
C) diastereotopic (**I**), neither enantiotopic nor diastereotopic (**II**), diastereotopic (**III**)

D) enantiotopic (**I**), neither enantiotopic nor diastereotopic (**II**), enantiotopic (**III**)

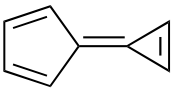
30. Which one of the following compounds has largest dipole moment?



I



II



III

A) **II**

B) **III**

C) **I**

D) All of them have equal dipole moment

31. How many normal modes does the CS_2 molecule have? How many of them can be observed using IR spectroscopy?

A) 3 modes, 2 can be observed

B) 6 modes, 5 can be observed

C) 4 modes, 3 can be observed

D) 3 modes, 3 can be observed

32. Light excitation of a molecule promotes an electron from a state $\phi_a(x,y,z)$ to $\phi_b(x,y,z)$, where x, y, z are spatial coordinates with respect to the molecular centre of mass. The change in the spatial position x of the electron can be calculated as:

A) $\int_{-\infty}^{\infty} \phi_b{}^*(x,y,z)\, x\, \phi_b(x,y,z)\, dxdydz \; - \int_{-\infty}^{\infty} \phi_a{}^*(x,y,z)\, x\, \phi_a(x,y,z)\, dxdydz$

B) $\int_{-\infty}^{\infty} \phi_b{}^*(x,y,z)\, x\, \phi_b(x,y,z)\, dx \; - \int_{-\infty}^{\infty} \phi_a{}^*(x,y,z)\, x\, \phi_a(x,y,z)\, dx$

C) $\int_{-\infty}^{\infty} \phi_b{}^*(x,y,z)\, \phi_b(x,y,z)\, dx \; - \int_{-\infty}^{\infty} \phi_a{}^*(x,y,z)\, x\, \phi_a(x,y,z)\, dx$

D) $\int_{-\infty}^{\infty} \phi_b{}^*(x,y,z)\, \phi_b(x,y,z)\, dxdydz \; - \int_{-\infty}^{\infty} \phi_a{}^*(x,y,z)\, \phi_a(x,y,z)\, dx$

33. A protein sequence in solution at temperature T folds from a denatured extended state to its native state. Under which of the following conditions on changes in enthalpy (ΔH) and entropy (ΔS) should such a transition be NOT favorable?

A) $0 > \Delta H > T\Delta S$

B) $\Delta H < 0 < T\Delta S$

C) $0 > T\Delta S > \Delta H$

D) $\Delta H = 0$ and $T\Delta S > 0$

34. A particle is thermally diffusing on a 1-dimensional harmonic potential given by $V(x) = \frac{1}{2}kx^2$, A where k is the spring constant and x is the position of the particle. The equilibrium probability $P(x)$ of finding the particle at a position x follows:

A) $P(x) \propto x^2$

B) $P(x) \propto x$

C) $P(x) \propto \exp(-Ax^2)$, where A is a constant

D) $P(x) \propto \exp(-Ax)$, where A is a constant

35. Which reaction has the greatest increase in entropy?

A) $C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$

B) $H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$

C) $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

D) $C_2H_4(g) + H_2(g) \rightarrow C_2H_6(g)$

36. A scalar coupling ($^2J_{1H\text{-}1H}$) constant for a doublet in compound X is measured as 5.0 Hz on a 500 MHz NMR spectrometer. Which of the following statements is incorrect?

A) The difference Δδ for the two components of the doublet depends on the field strength of the spectrometer.

B) For this doublet, the coupling constant measured in Hz depends on the field strength of the spectrometer.

C) For this doublet, the coupling constant is 5.0 Hz when the spectrum of X is recorded on a 250 MHz NMR spectrometer

D) The difference Δδ for the two components of this doublet is 0.05ppm when measured on a 100MHz spectrometer.

37. What is the last digit of 3^{4798} ?

A) 3

B) 9

C) 1

D) 7

38. In a face centered arrangement of A and B atoms. Where A atoms are at the corners of the unit cell and B atoms are at the face centers. For each unit cell, one A atom is missing from a corner position and one B atom is missing from one face position. The simplest formula of the resulting compound will be:

A) $A_{14}B_{40}$

B) A_7B_{20}

C) $A_{1-x}B_{3-x}$

D) AB_2

39. Iron, Cobalt and Nickel are three known elements that display ferromagnetism. Which of the following statements is true about ferromagnets:

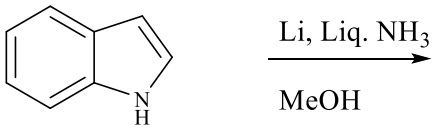
A) In the presence of a magnetic field, the unpaired spins of a ferromagnet all align with the external field. Then in the absence of the external magnetic field, these spins then revert back immediately to their original state.

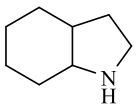
B) The origin of magnetism in a ferromagnet arises from randomly arranged paired spins in a lattice.

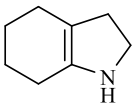
C) A ferromagnetic material is weaker (in its attraction to an external magnetic field) than a paramagnetic material

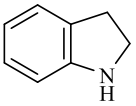
D) None of the above.

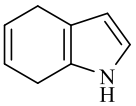
40. The major product formed in the following reaction is



A) 

B) 

C) 

D) 

D.

The following question does NOT carry any marks and is given to collect information only:

41) How much time did you take to complete this chemistry exam?

A) Less than 1 hour

B) Between 1 to 2 hours

C) Between 2 to 3 hours

D) Insufficient time was given