

HOMI BHABHA CENTRE FOR SCIENCE EDUCATION
TATA INSTITUTE OF FUNDAMENTAL RESEARCH

Entrance Test for Ph.D. Programme in Science Education – 2013

Section I

Scientific literacy, Technical comprehension, and Logical reasoning

Read the following instructions carefully.

- This section of the written test carries **60 marks** and is of **one hour** duration.
- This section of the question paper consists of 9 pages. There are four passages in this section. Each passage is followed by five multiple choice questions based on the passage text. Read the text carefully and indicate your answers. Remember that more than one option might appear to be correct. You have to find the most correct response. The answers must be marked on the separate **Answer Sheet** provided.
- All questions are of multiple choice type with four options, out of which only ONE option is correct. Each correct answer earns 3 marks. An unanswered question or a wrong answer earns no mark.
- Before you start answering, please check that you have written your Name and Roll Number on both sides of the Answer Sheet.
- You must indicate your answers **only on the Answer Sheet provided**, by putting a \times in the appropriate box against the relevant question number, like this: . Use a dark ink pen to indicate your answers.
- Think and decide carefully on your answer before you indicate it on the Answer Sheet. In case you want to change your answer for a particular question after you have already put a \times in a certain box, blacken out the entire box and put a \times in the new box of your choice. In the example below the initial choice of (B) has been changed to (C):
(A) (B) (C) (D) (A) (B) (C) (D)
 \rightarrow
- At the end of one hour, please submit this question paper but **keep the Answer Sheet with you**.

1.—5. Read the following passage, and then find the right answer to each of the next five questions from the choices provided.

The expansion of the universe, tectonic plate drift, evolution of the species, and molecular structure and reactivity are all scientific phenomena that are not available to direct experience. Whether the phenomenon is cosmological, geological, biological, or chemical, our window on the world is really very small. But perhaps more than other sciences, understanding chemistry relies on making sense of the invisible and untouchable. Much of what is chemistry exists at a molecular level and is not accessible to direct perception. Whereas the experiments used in classroom demonstrations are carefully selected to denote chemical processes by changing color, precipitating a solid, or giving off heat, most chemical reactions in the real world occur at rates that are so fast or slow, or their products are so dispersed, colorless, or odorless, as to make them difficult to detect.

Consequently, chemistry as a field of study is inherently representational or symbolic. Chemists have invented specialized symbol systems – such as reaction equations, molecular structure diagrams, concentration graphs, and three-dimensional (3D) computer models – to represent the molecular phenomena that they study in their laboratories, and they use these to communicate their understanding to their peers. Chemists also use these representations to communicate their understanding to students. Classroom whiteboards and modern chemistry textbooks are filled with diagrams, charts, graphs, equations, and formulas along with words, photographs, and illustrations. Increasingly, newer educational technologies – video and computers – are also being used in the classroom to represent chemical phenomena in new ways. But do chemistry students understand these representations to mean what chemists intend? Do they have the necessary prior knowledge to begin to see the principles in the images?

Research on expertise distinguishes experts from novices primarily by the ways they organize their knowledge in a domain and use this knowledge to solve problems and understand the world around them. The knowledge of experts consists of a large number of interconnected elements that are stored and recalled as extended, coherent chunks of information organized around underlying principles in the domain. Experts use the structure of this knowledge to perceive and recognize underlying patterns and principles in problem situations; they virtually “see” a problem different from the one novices do. For example in response to a typical textbook physics problem, expert physicists evoke underlying principles such as force or energy. They use these principles to build a mental representation, or mental model, of the situation that includes mental entities corresponding to both the physical objects encountered in the problem (such as blocks, springs, pulleys, etc.), as well as formal constructs (such as force vectors, friction, and velocity) that have no direct, concrete referent in the real world. Experts use this mental model to test and select potential problem solutions. In contrast, the knowledge of novices is sometimes characterized as unconnected fragments that correspond to common experiences with the everyday world, experiences such as pushing, throwing, and overcoming an opposing force.

1. We cannot perceive most chemical reactions because:

- (A) They happen too fast or too slow.
- (B) Their products are colourless and odourless.
- (C) Our perceptual system is limited.
- (D) Our window on the world is very small.

2. Why is chemistry inherently symbolic?

- (A) Because molecular phenomena cannot be observed.

- (B) Because symbols provide a way of thinking systematically about unobservable molecular entities.
- (C) Because representing molecular phenomena as symbols make them easy to understand.
- (D) Because symbolic representation makes it easy to communicate discoveries.

3. The basis of organization of experts' knowledge is:

- (A) Extended information
- (B) Underlying principles
- (C) Interconnected elements
- (D) Coherent chunks

4. What is the critical difference between the knowledge of physics experts and novices?

- (A) Experts only use formal constructs such as force vectors and velocity.
- (B) Experts use objects in the problem and formal constructs.
- (C) Experts create and test mental models.
- (D) Experts do not use everyday experiences.

5. The article suggests that expertise in chemistry requires:

- (A) Learning many molecular structures.
- (B) Learning many symbols
- (C) Recognizing patterns
- (D) Understanding basic principles

6.—10. Read the following passage, and then find the right answer to each of the next five questions from the choices provided:

Music moves us, literally. All human cultures dance to music and music’s kinetic faculty is exploited in everything from military marches and political rallies to social gatherings and romance. This cross-modal relationship is so fundamental that in many languages the words for music and dance are often inter-changeable, if not the same. We speak of music “moving” us and we describe emotions themselves with music and movement words like “bouncy” and “upbeat”. Despite its centrality to human experience, an explanation for the music-movement link has been elusive.

It is possible that music and movement share a dynamic structure. Such a shared structure is consistent with several findings from research with infants. It is now well established that very young infants – even neonates – are predisposed to group metrically regular, auditory events similarly to adults. Moreover, infants also infer meter from movement. In one study, 7-month-old infants were bounced in duple or triple meter while listening to an ambiguous rhythm pattern. When hearing the same pattern later without movement, infants preferred the pattern with intensity (auditory) accents that matched the particular metric pattern at which they were previously bounced. Thus, the perception of a “beat,” established by movement or by music, transfers across modalities. Infant preferences suggest that perceptual correspondences between music and movement, at least for beat perception, are predisposed and therefore likely universal. By definition, however, infant studies do not examine whether such predispositions survive into adulthood after protracted exposure to culture-specific influences. For this reason, adult cross-cultural research provides important complimentary evidence for universality.

Previous research suggests that several musical features are universal. Most of these features are low-level structural properties, such as the use of regular rhythms, preference for small-integer frequency ratios, hierarchical organization of pitches, and so on. We suggest music’s capacity to imitate biological dynamics, including emotive movement, is also universal. This capacity also arises from the fundamental dynamic similarity of the domains of music and movement. Imitation of human physiological responses would help explain, for example, why “angry” music is faster and more dissonant than “peaceful” music. This capacity may also help us understand music’s inductive effects: for example, the soothing power of lullabies and the stimulating, synchronizing force of military marching rhythms.

6. What could be wrong with the statement “all human cultures dance to music”?
- (A) It is not clear what is meant by “human culture”.
 - (B) Videos on the internet show parrots dancing to music.
 - (C) There are some cultures where people do not dance when music is played.
 - (D) There are some cultures where people dance when no music is played.
7. In some languages, words for music and dance are often inter-changeable. What does this indicate?
- (A) Music and dance usually occur together.
 - (B) Music is usually played for dance.
 - (C) These languages do not distinguish between music and dance.
 - (D) Speakers of these languages consider music and dance to have some features in common.
8. The infant bouncing study is not a convincing experiment because:

- (A) It did not have a pre-test, showing that infants did not prefer the same beat before bouncing.
- (B) There was no control condition, where one group of infants were not rocked at all.
- (C) It does not show that infants are pre-disposed to make correspondences between music and movement patterns.
- (D) It does not show that there is a universal ability to make correspondences between music and movement.

9. Does the infant-bouncing study show that the correspondence between music and movement is universal?

- (A) Yes, because the correspondence is shown to exist at such a young age.
- (B) No, because even if such a correspondence exists during infancy, this could be changed by cultural experiences.
- (C) Yes, because universality is the best possible explanation for the infant study results.
- (D) No, because every baby is different.

10. What is the explanation proposed for why “angry” music is faster and more dissonant than “peaceful” music?

- (A) Music can produce emotions, such as calming by lullabies.
- (B) Emotions and music are produced by similar physiological responses.
- (C) Music imitates biological movement, including movement related to emotions.
- (D) Faster music makes people angry and slower music make people feel at peace.

11.—15. Read the following passage, and then find the right answer to each of the next five questions from the choices provided:

At nightfall, the Hawaiian bobtail squid digs itself out of the sand and rises into the ocean water. It switches on its cloaking device: glowing bacteria inside its body light up, disguising the squid's silhouette against the moonlight for any predators swimming below.

Hiding during the day and hunting at night in shallow Pacific waters, *Euprymna scolopes* clearly has a working circadian clock. Researchers had noticed, though, that the squid's light organ seemed to have a rhythm of its own. The *Vibrio fischeri* bacteria give off fluctuating amounts of light throughout the day, for one thing. And the bacteria have their own daily rhythm of gene expression (when various genes are turned on or off).

Researchers looked for genes linked to circadian rhythms within the squid. They found two types of "cry" genes, which are known to control internal clocks throughout the animal and plant kingdoms. One gene had a daily cycle of activity in the squid's head which is what you would expect, since animals' main circadian clocks are in their brains. Other clocks can be elsewhere in the body, though, and this is what researchers found with the second cry gene. It was cycling only within the light organ.

Baby squid, which had not yet collected bacterial friends in their light organs, did not show the same cycling. So it seemed that the bacteria themselves were driving the daily rhythms in the light organ. When the researchers let squid fill their light organs with defective, non-glowing bacteria, the cry gene still did not cycle properly. This suggested that the glow of the bacteria was the crucial ingredient.

To test this idea, the scientists shone a blue light on the squid holding defective bacteria. Now they expressed just as much cry as the original squid.

Cryptochromes, the proteins made by cry genes, respond to blue light. Based on the light signals the cryptochromes receive, they turn other genes on or off. Cryptochromes in the squid's head respond to light from the sun to drive its daily rhythms, as in other animals and plants. Those in its light organ, though, respond to the light of its glowing bacterial companions.

The role of the bacterial clock is not clear yet. "We don't know if the light organ rhythms control any other rhythms in the body," says a researcher. "But they certainly seem to be involved in controlling the rhythms of the organ itself." The squid controls the daily schedule of the bacteria, too: it jettisons most of its bacteria in the morning, and seems to keep them dimmed during the day by restricting their oxygen supply. At night, it gives the bacteria enough resources to glow at full strength – and that glow drives the clock within the light organ. The researcher says, "the host and symbiont 'talk' to one another, controlling one another's biology."

The idea that bacteria can drive circadian rhythms inside their hosts is exciting to humans because we, too, are animals packed full of bacteria. Ours do not glow, but they do line our guts and participate in digesting our food. The researcher points out that scientists have found "profound circadian rhythms" within our gut tissues, both in their activity and in what genes they express.

Even though we are land-bound, non-glowing vertebrates, our bacteria could be powering circadian rhythms within our bodies just like the squid's. "We think it might be a very general phenomenon," says the researcher.

11. The researchers let the baby squid fill their light organs with defective, non-glowing bacteria, because:

- (A) The researchers wanted to test if presence of bacteria could activate the light organ.

- (B) Researchers wanted to test the hypothesis: The cry genes of baby squids were not cycling properly because baby squids lack bacteria.
- (C) The researchers wanted to see if the glow of the bacteria was required to activate the light organ.
- (D) The researchers wanted to see how bacteria influenced the baby squid's response to light.

12. What possible inference could the scientists have drawn if the squid holding defective bacteria had not expressed cry genes in response to the blue light?

- (A) Baby squid cry genes do not respond to blue light.
- (B) There is some factor in baby squid metabolism that blocks the response to blue light.
- (C) Defective bacteria block the blue light response of cry genes.
- (D) Scientists could not have drawn any principled inference.

13. The role of the bacterial clock is not clear yet because:

- (A) Both squid and bacteria influence each other's metabolism.
- (B) The clock is indirectly controlled by the squid.
- (C) The bacteria's resources is controlled by the squid.
- (D) The bacteria could be controlling the squid through other mechanisms.

14. This research shows that:

- (A) Bacteria control the squid.
- (B) The squid controls the bacteria.
- (C) Nothing can be said about control of the two organisms.
- (D) Both organisms control each other.

15. A possible reason for this research NOT being relevant to humans is:

- (A) Most of our bacteria is in our gut, and they do not emit light.
- (B) It has not been shown that our circadian rhythms are connected to our bacteria.
- (C) We have bacteria, but we do not have control over the bacteria like the squid do.
- (D) Our circadian rhythms are brain-based.

16.—20. Read the following passage, and then find the right answer to each of the next five questions from the choices provided:

Contrary to some earlier research, recent studies of global income inequality find that, when China and India are given their due weight, global income inequality is not rising. To be clear, there is massive global income inequality in the world today – but it is not growing rapidly, as once feared. The “yes it is/no it isn’t” story of rising global income inequality provides a good example of the importance of knowing what it is that you are trying to explain before you try to explain it. In a number of popular articles and books, inequality has been linked to economic globalization, one of the hottest topics in social science, to fashion a growing literature on globalization and the “explosion” of global income inequality. But the argument that globalization is the cause of rising global income inequality is wrongheaded – it tries to explain a “fact” that isn’t. It is instructive to see where the earlier research went wrong. Income inequality refers to the disproportionate distribution of income across individuals or households. Social scientists have devised ways to measure disproportionality in income. By applying these measures to income data over time we can determine whether income inequality is rising or falling for a country – or even the whole world.

Global income inequality refers to the disproportionate distribution of income across all the world’s citizens, where each citizen is given equal weight.; With regard to the discussion here, the important point to note is that the claim of rapidly growing global income inequality in earlier research was subject to challenge because it rested on a series of dubious assumptions and incomplete analyses. These included:

- *Extrapolation from results for the tails of the income distribution.* Some earlier studies concluded that global income inequality is rising rapidly on the basis of a comparison of income trends for the very richest and very poorest countries. But the vast majority of the world’s people live somewhere else. We cannot reach defensible conclusions about the inequality trend for all the world’s population by examining income trends only for those who live in the very richest and very poorest regions.
- *Unequal weighting of individuals.* Early studies often weighted all countries equally. However, because global income inequality refers to the unequal distribution of income across individuals – and many more individuals live in poor countries (e.g., China) where incomes are growing rapidly than in poor countries where incomes are growing slowly – the failure to weight countries by their population produced misleading results in those studies.
- *Extrapolation from historical trends.* Global income inequality rose rapidly over the nineteenth century and the first half of the twentieth as the West took off economically and Asia and Africa lagged behind. Global income inequality rose rapidly because the richest regions of the world were the world’s growth leaders and the poorest regions tended to grow slowly, if at all. In recent decades, however, the world has changed. Now many of the fastest growing economies are in poorer regions of the world – a point not fully taken into account in some early studies. Because income inequality is now declining across countries, the longstanding growth in global income inequality has halted. At the same time, income inequality has increased within many countries. Declining inequality across countries and rising inequality within them implies a “new geography of global income inequality” in which countries are receding in importance as economic units.

16. Which of these may be a rough measure of the income inequality in India?

- (A) The ratio of the average income per adult in India and the average income per adult for the world as a whole.
- (B) The ratio of the average income per adult in India and the average income per adult for

the world as a whole after adjusting for purchasing power parity.

- (C) The ratio of the average income per adult in India and the average income per adult in a country with a similar population like China.
- (D) The ratio of the salary of a corporate manager and the wage of a farm labourer in India.

17. From what the author says in the above passage, we can conclude that

- (A) Income inequality is growing faster in countries like India and China than in poorer countries.
- (B) Income inequality is growing faster in countries with more advanced economies than in India and China.
- (C) By giving all countries equal weight, some studies showed that global income inequality is rising.
- (D) Income inequality in a country depends on the rate of population growth in a country.

18. Consider the following three statements:

- I. Income inequality across countries is declining.
- II. Income inequality within many countries is increasing.
- III. Income inequality across countries is no longer an adequate measure of inequality.

According to the author of the passage,

- (A) I, II and III are true, but all of them are independent facts.
- (B) I, II and III are true; III is a consequence of I alone and is independent of II.
- (C) I, II and III are true; III is a consequence of I and II.
- (D) I and II are true, but III is false.

19. According to the author, the main reason why global income inequality rose rapidly till the mid-twentieth Century is

- (A) There was a direct correlation between high rates of economic growth and high income among countries.
- (B) There was an inverse correlation between high rates of economic growth and high income among countries.
- (C) The poorer countries were colonies of the richer countries.
- (D) The richer countries had higher national income than the poorer countries.

20. The author's main criticism of studies that linked economic globalization to rising global inequality is that

- (A) The studies assumed that economic globalization was a fact, while it was not.
- (B) The target of the explanation provided by these studies was incorrectly assumed to be true.
- (C) The explanation provided for rising global inequality must be based on better data.
- (D) The correct explanation for rising global inequality is the rapid economic growth of large countries like China and India.

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Section II: Scientific Aptitude

Read the following instructions carefully.

- This section of the written test is on scientific knowledge and aptitude. It covers broadly the areas of Biology, Chemistry, Mathematics, Physics, and general knowledge, including social sciences and education.
- This section of the question paper consists of 12 pages. It has 50 questions, carrying a total of 150 marks. The questions can be categorised according to subject area as follows:

Subject	Question nos.
General	21–30
Biology	31–40
Chemistry	41–50
Mathematics	51–60
Physics	61–70

- **You may answer as many questions as you want from any subject area. While you might not be able to answer all the 50 questions in the time provided, you should try to maximise the number of correct answers.** It is a good idea to answer the questions on your area of strength first.
- All questions are of multiple choice type with four options, out of which only ONE option is correct. Each correct answer earns a credit of 3 marks. **A wrong answer carries a penalty of –1 mark.** An unanswered question carries no credit or penalty.
- You must indicate your answers **on the reverse side of the same Answer Sheet that you used for Section I of this test**, by putting a × in the appropriate box against the relevant question number, like this: . Indicate your answers using a pen to make a dark mark.
- **Please carefully choose the section of the answer sheet pertaining to the subject that you are answering questions on. Check the question number before putting down your answer.**
- Think and decide carefully on your answer before you indicate it on the Answer Sheet. In case you want to change your answer for a particular question after you have already put a × in a certain box, blacken out the entire box and put a × in the new box of your choice. In the example below the initial choice of (B) has been changed to (C):

(A) (B) (C) (D) (A) (B) (C) (D)
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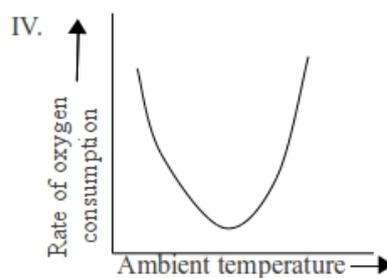
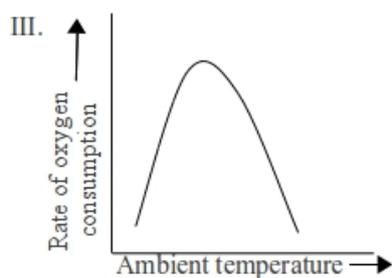
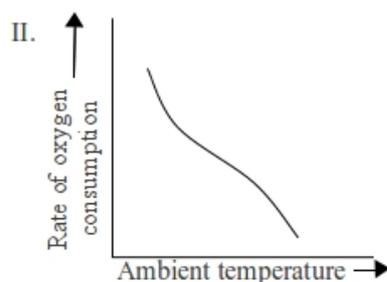
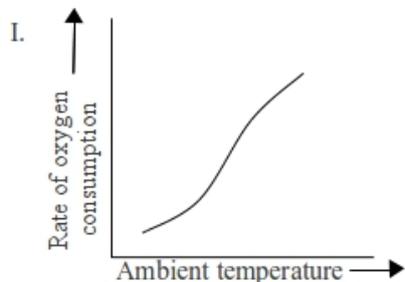
- Use of non-programmable scientific calculators is permitted.
- For rough work, you may ask the invigilator for extra sheets of paper.
- At the end of the test, please submit this question paper, the Answer Sheet, and any extra sheets that you may have used.

21. Apu, a small child, cries every time he hears a loud noise. His neighbours' dog often barks very loudly. Apu cries every time he sees the dog. What is the conditioned stimulus in this case?
- (A) barking
 - (B) dog
 - (C) a loud noise
 - (D) crying
22. A cat attacked Mini. After this incidence she started fearing all cats. She attended counselling sessions in which she was taught to relax in the presence of cats. How would you explain that she now no longer fears cats?
- (A) Mini spontaneously recovered.
 - (B) Mini learned to discriminate.
 - (C) There was an extinction of Mini's fear.
 - (D) Mini went through counter conditioning.
23. A community of people uses a concept they call zoog. A researcher believes that zoogs exist in the world only because the community uses it. Such a person is
- (A) A realist
 - (B) An idealist
 - (C) A pragmatist
 - (D) An existentialist
24. For playing a game of chess which one of the following intelligences is most essential?
- (A) Kinesthetic
 - (B) Visuo-spatial
 - (C) Logical- mathematical
 - (D) Interpersonal
25. If it is 6.00 am on 0° meridian, what is the time in India? (The longitude used for determining Indian Standard Time is 82.5° E.)
- (A) 9:30 am (B) 11:30 am (C) 9:30 pm (D) 11:30 pm
26. The centre of the earth is the farthest from
- (A) North pole
 - (B) South pole
 - (C) Both north and south poles
 - (D) Equator

27. I am celebrating Christmas in a city in the summer. I must be in
(A) Madrid (B) Melbourne (C) Moscow (D) Mumbai
28. The following is an example of negative correlation:
(A) An industry which has poor infrastructure retards production
(B) Low self concept leads to low performance
(C) Growth in population leads to decrease in per capita living space
(D) Increase in practice leads to enhanced performance
29. A student studies hard, but does not pass an entrance test of a research institute. He tells his friends that he never really wanted to do research. He was using the defence mechanism of
(A) Compensation
(B) Conversion
(C) Denial
(D) Rationalization
30. Two groups of people have been fighting for over a decade. At a point in time, they resolve not to continue the fight in order to get some benefit for each side (group). However, the cause of the fight still remains unresolved. The social process involved is
(A) Accommodation
(B) Assimilation
(C) Cooperation
(D) Integration
31. A mixture of Mucor (bread mold), yeast and rice paste are mixed in a container. The container is covered and kept undisturbed. What is most likely to occur at the end of a few hours?
(A) Mucor is likely to ingest some of the starch and yeast cells and use them as a source of energy.
(B) Mucor and yeast both being heterotrophs, will not be able to use rice as a food source. Hence there will be no change in the composition of the mixture.
(C) Mucor will release extracellular enzymes to digest starch to glucose. Yeast will ferment glucose to make alcohol.
(D) Yeast cells will take up starch molecules, digest them intra-cellularly and release the sugar molecules in the container. These sugars will be absorbed by Mucor.
32. Water plant hydrilla was immersed in three test tubes (P, Q and R) each containing three different solutions. All the three tubes were kept under sun light. When observed after a couple of minutes, evolution of bubbles escaping from the hydrilla stem was much faster in test tube Q as compared to tubes P and R. The three solutions respectively could be:
(A) Dilute NaOH, water, dilute NaCl solution.

- (B) Dilute glucose solution, dilute H_2O_2 solution, water.
- (C) Dilute HCl solution, dilute NaHCO_3 solution, water.
- (D) Water, dilute KCl solution, water.

33. If the rate of metabolism for a frog is plotted against the environmental temperature, which of the following graphs will be obtained?



- (A) I (B) II (C) III (D) IV

34. Treatment of tuberculosis in patients that harbour multidrug-resistant tuberculosis (MDR-TB) is becoming difficult. MDR-TB do not respond to treatment with first-line anti-TB drugs, for example the antibiotic rifampicin (RMP). The significant reasons which underlie the emergence of MDR-TB include: doctors giving inappropriate treatment, or patients missing doses or failing to complete their treatment. Under these conditions, *Mycobacterium tuberculosis* (the causative bacteria) are evolving to develop resistance to drugs. For example, in a particular place, between 2008 and 2011 resistance to RMP increased from 1 % to 3.5 %. Scientists attribute this to natural selection. What does natural selection mean in this context?

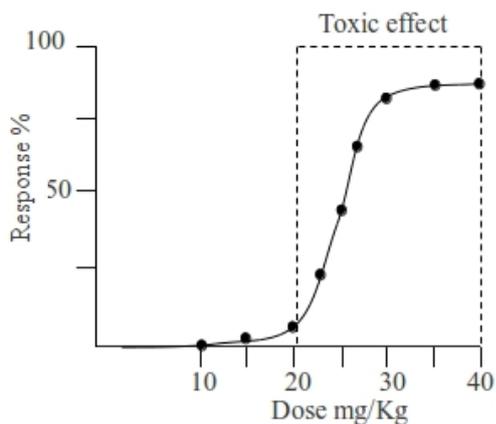
- (A) Irregular dosage created an environment in which bacteria harboring antibiotic-resistant genes could flourish.
- (B) RMP has changed the genetic structure of the bacteria allowing them to become antibiotic-resistant.
- (C) The bacteria changed their genetic code in order to avoid problems with the antibiotic.
- (D) The mutation rate for antibiotic-resistance increased during the time period.

35. How many amino acids exist?

- (A) 19 (B) 20 (C) 21 (D) more than 21

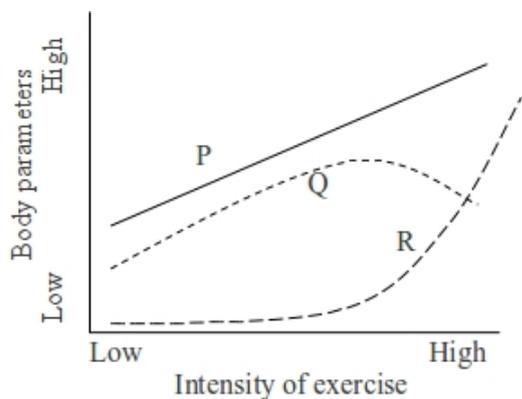
36. Whenever a new drug is tested for any ailment, its toxicity study is very important. In order to

study it, a graph is plotted that shows the dose on one axis and the response or effects on the other. Study the following dose response curve and mark the correct statement.



- (A) The lowest dose at which adverse effect is observed is 10 mg.
- (B) The highest dose at which no adverse effect is observed is 20mg.
- (C) The lowest dose at which an adverse effect is observed is 25 mg.
- (D) The highest dose at which an adverse effect is observed is 30 mg.

37. Various physiological changes occur in body when a person initially at rest starts exercising. The changes also depend on the extent of the exercise. In the following graph, three such parameters (P, Q and R) are depicted.



They respectively represent:

- (A) Oxygen consumption, CO₂ production, body temperature
- (B) Muscle contraction, heart rate, CO₂ production
- (C) Lactic acid production, CO₂ production, body temperature
- (D) Heart rate, oxygen consumption, lactic acid production

38. Which of the following sequences shows increasing order of pesticide accumulation in the respective bodies as measured in ratio of amount of pesticide to body size?

- (A) shrimps, diatoms, mackerel, large shark
- (B) diatoms, shrimps, mackerel, large shark
- (C) large shark, diatoms, shrimps, mackerel
- (D) large shark, mackerel, shrimps, diatoms

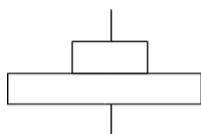
39. An enzyme has a lysine, along with two other amino acids, in its active site (site where the substrate binds and is ultimately transformed to product). This lysine, an amino acid with a four carbon long side chain that terminates in an amino (NH_3^+) group, participates in hydrogen bonding with the substrate and helps orient the substrate in the active site for catalysis. To determine the importance of this lysine, it was replaced by alanine, which has a short non-reactive methyl (CH_3) for its side chain. The enzyme activity assays were then performed to determine the kinetic properties – K_m (Michelis-Menten constant, that reflects the substrate binding properties) and K_{cat} (enzyme activity). Following were the results obtained for the wildtype enzyme (with lysine) and the mutated enzyme (lysine replaced by alanine):

	K_m (mM)	K_{cat} (min^{-1})
Wildtype enzyme	5	80
Mutated enzyme	5	35

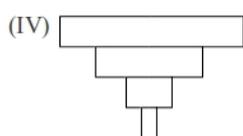
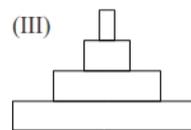
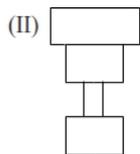
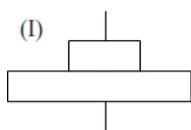
Which of the following best explains the observed measurements?

- (A) Loss of hydrogen bonding resulted in unstable substrate binding causing decreased enzyme activity.
- (B) Loss of hydrogen bonding resulted in more stable substrate binding causing decreased enzyme activity.
- (C) Loss of hydrogen bonding resulted in stronger substrate binding, but the altered spatial orientation of the substrate in the active site caused decreased enzyme activity.
- (D) Loss of hydrogen bonding did not affect substrate binding, but the change in side chain length altered spatial orientation of the substrate in the active site causing decreased enzyme activity.

40. Data were collected for an ecosystem consisting of a mango tree, caterpillars, birds and a sparrow hawk. When the number pyramid was plotted, it looked as follows:



Which of the following will be the shape of energy pyramid for this ecosystem?



- (A) I (B) II (C) III (D) IV

41. A 20.0 mL sample of an element (density 3.0 kg m^{-3}) contains 4×10^{23} atoms. The atomic mass of the element is

- (A) 9 (B) 90 (C) 12 (D) 24

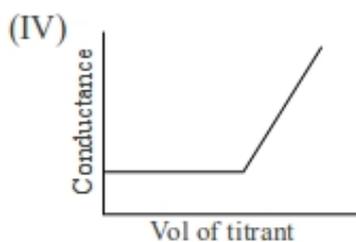
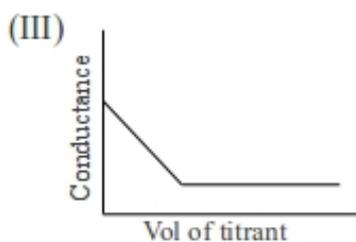
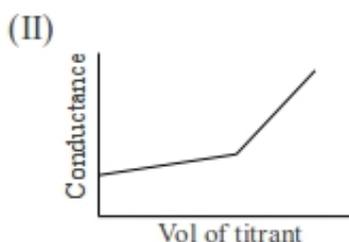
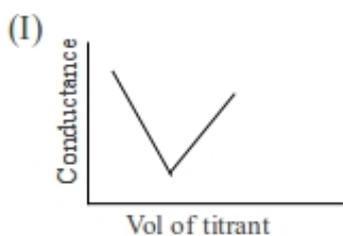
42. The IUPAC name of  is

- (A) methyl 3-hexenoate
- (B) 3-hexenemethyl carboxylate
- (C) 3-butenyl acetate
- (D) methyl 2-hexenoate

43. In an ionic compound, the cation is usually smaller than the anion. But it is possible to have an ionic compound where the reverse is true. The compound in which the cation is larger than the anion is

- (A) magnesium iodide
- (B) lithium chloride
- (C) calcium bromide
- (D) caesium fluoride

44. In the conductometric titration of H_2SO_4 vs NH_4OH , the titration curve obtained will be of the type



- (A) I (B) II (C) III (D) IV

45. Analysis of a compound known to contain only Mg, P, and O showed the following results: 21.8% Mg, 27.7% P and 50.3% O. What is its empirical formula?

- (A) MgPO_2 (B) MgPO_3 (C) $\text{Mg}_2\text{P}_2\text{O}_7$ (D) $\text{Mg}_3\text{P}_2\text{O}_8$

46. In SF_6 , the hybridisation of sulphur is

- (A) sp^3d^2 (B) sp^3d (C) sp^3 (D) dsp^2

47. At equilibrium, the change in the Gibbs free energy of a reaction is
- (A) greater than zero
 - (B) equal to zero
 - (C) minimum
 - (D) less than zero
48. The amount of cyclohexanol (in g) that must be reacted to produce 20 g of cyclohexene, if the yield is 54%, is
- (A) 10.8
 - (B) 4.5
 - (C) 45
 - (D) 37
49. The half life of a radioisotope is 3.9×10^4 years. The time after which $1/32$ of the original sample remains would be
- (A) 3.9×10^5
 - (B) 1.95×10^5
 - (C) 2.4×10^5
 - (D) 1.25×10^6
50. The van der Waals equation for real gases is
- $$(P + a(n/V)^2)(V - nb) = nRT$$
- In the above equation, the terms $a(n/V)^2$ and (nb) respectively represent the corrections for
- (A) intermolecular attractive forces and inelastic collision
 - (B) intermolecular repulsive forces and high temperatures
 - (C) intermolecular attractive forces and molecular volumes
 - (D) deviations in the temperature and pressure
51. The graph of $y = |x - 1|$ can be obtained by translating the graph of $y = |x|$ by one unit along the
- (A) positive direction of the x -axis.
 - (B) negative direction of the x -axis.
 - (C) positive direction of the y -axis.
 - (D) negative direction of the y -axis.
52. The equation $ax^2 + bx + c = 0$, with a, b, c real numbers and $a \neq 0$, has real roots. Which of the following equations **DOES NOT** have a real root?
- (A) $ax^2 + 2bx + c = 0$
 - (B) $ax^2 + bx + a + \frac{b^2}{4a} = 0$
 - (C) $2ax^2 + 2bx + c = 0$
 - (D) $4ax^2 + 2bx + c = 0$
53. If the area of an expanding circular region increases at a constant rate (with respect to time), then the rate of increase of the perimeter with respect to time

- (A) varies inversely as the radius.
- (B) varies directly as the radius.
- (C) varies directly as the square of the radius.
- (D) remains constant.

54. Three shops A, B, C sell identical products. The prices on day one are same in all the three shops. On day two, shop A offers a 10% discount, shop B offers a 15% discount, and shop C offers a 20% discount. On day three, shop A offers a further 20% discount, shop B offers a further 15% discount, and shop C offers a further 10% discount. Which of the following is true?

- (A) Prices in all the shops are same.
- (B) Prices in shop A and shop C are same, which is lower than the price in shop B .
- (C) Price in shop A is less than price in shop B , which in turn is less than price in shop C .
- (D) Price in shop A is greater than price in shop B , which in turn is greater than price in shop C .

55. Two poles A and B of heights 10 and 20 meters are made to stand vertically with a distance of 30 meters between them. An elastic rope connects the top of A and the bottom of B , and another such rope connects the top of B and the bottom of A . Let h denote the height at which the two ropes meet. Now the poles are moved (in the horizontal direction) such that the distance between the two poles is 60 meters. Let H denote the height at which the two ropes meet. Which of the following relations between h and H holds?

- (A) $H = h$.
- (B) $H = 2h$.
- (C) $H = h/2$.
- (D) $H = \sqrt{2}h$.

56. A ladder is standing vertical and is resting against a wall. A cat is sitting at the centre of the ladder. The ladder now slides with its top end touching the wall, and the other end sliding on the floor. Then the path traced by the cat is

- (A) a segment of a straight line.
- (B) an arc of a circle.
- (C) a part of a parabola.
- (D) a part of an exponential curve.

57. Hundred students take a test that consists of 50 problems. It is known that each problem is solved by the same number of students and each student solved exactly 20 problems. Then the number of students who solved a particular problem is

- (A) 10.
- (B) 20.
- (C) 40.
- (D) 80.

58. Two natural numbers a and b are such that their sum is 2013. Which of the following statements is always true about the product of these numbers?

- (A) The product is divisible by 4.
- (B) The product is less than 10^6 .
- (C) The remainder when the product is divided by 3 is not 1.
- (D) None of the above.

59. Three cylindrical beakers A, B, C have circular base of radii 1, 7, 35 units, respectively. Each of them is filled with water to the same height. Some water is transferred between A and B so that those two beakers have the same volume of water. Some water is then transferred between A and C so that those two beakers now have the same volume of water. Which of the following statements is **false**?

- (A) A has more volume of water than B .
- (B) B has less volume of water than C .
- (C) The height of water in B and C are same.
- (D) None of the above.

60. Let f be a continuous function from the set of positive reals to itself such that given any $\alpha > 0$ one can find a positive real r such that $f(r) > \alpha$. In other words, the function f takes arbitrary large values. Which of the following statements is **always false**?

- (A) $\int_0^\infty f(x)dx$ is finite.
- (B) $\lim_{x \rightarrow 0} f(x)$ exists.
- (C) $\lim_{x \rightarrow \infty} f(x)$ exists.
- (D) Both $\lim_{x \rightarrow 0} f(x)$ and $\lim_{x \rightarrow \infty} f(x)$ exist.

61. Water droplets from a dripping tap or on leaf surfaces are spherical because:

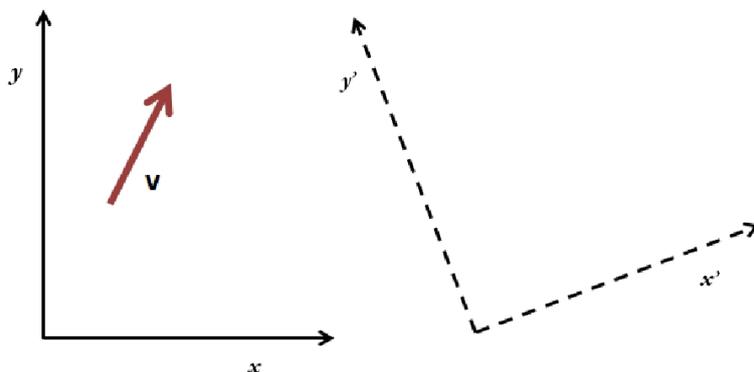
- (A) The density of water is greater than density of air.
- (B) The force of gravity on each droplet is balanced by the air pressure on its surface.
- (C) The net force on the surface molecules of the droplet is different from that on its interior molecules.
- (D) The spherical shape conserves the momentum of the droplet.

62. Two metal balls A and B of same volume, and both with greater density than water, are dropped into two identical glasses of water G_a and G_b . Mass of A is 3 times that of B . The relative rise in the level of water

- (A) is the same in both glasses.
- (B) in glass G_a is 3 times that in G_b .
- (C) in glass G_b is 3 times that in G_a .
- (D) in the two glasses cannot be concluded from given data.

63. In the left figure below, a vector \mathbf{v} is in a reference frame with orthogonal x and y axes. The axes are then rotated anticlockwise by 25° about the fixed origin. The new axes are x' and y' as shown

on the right. Which one of the following statements about vector \mathbf{v} in the rotated reference frame is correct?



- (A) Magnitude of vector \mathbf{v} is smaller in the rotated co-ordinate system.
- (B) Magnitude of vector \mathbf{v} is greater in the rotated co-ordinate system.
- (C) The x-component of vector \mathbf{v} is smaller in the rotated co-ordinate system.
- (D) The x-component of vector \mathbf{v} is greater in the rotated co-ordinate system.

64. Read the following passage. A few incorrect statements have been introduced in the passage.

In 1905 Albert Einstein published a paper that explained experimental data from the photoelectric effect as being the result of light energy being carried in discrete quantized packets. This discovery led to the quantum revolution. Einstein was awarded the Nobel Prize in 1921 for his discovery of the law of the photoelectric effect. The photoelectric effect requires photons with energies from a few keV (kilo electron volts) to over 1 MeV in high atomic number elements. Study of the photoelectric effect led to important steps in understanding the quantum nature of light and electrons, and influenced the formation of the concept of waveparticle duality. Other phenomena where light affects the movement of electric charges include the photoconductive effect, the photovoltaic effect, and the photoelectrochemical effect. It also led to Max Planck's discovery of quantized energy and the Planck Relation ($E = h\nu$), which links a photon's frequency with its energy. The factor h is known as the Planck constant.

Which one of the following is a correct statement?

- (A) Photoelectric effect requires photon energy to be in the range of MeV.
- (B) Einstein was the first to postulate the quantization of energy.
- (C) The Planck energy relation is $E = h\nu$.
- (D) Einstein was awarded the Nobel Prize for his theory of special relativity.

65. Two pendulums attached to the roof of a room are oscillating side-by-side, but are not connected to each other. They have different time periods. Which one of the following statements is true?

- (A) The centre of mass of the two pendulums are at different heights from the ground
- (B) The two pendulums have different values of mass.
- (C) Their amplitudes of oscillation must necessarily be different.
- (D) Their velocities at the extreme points in their oscillations must be different.

66. A metal has electrons that require close to 8 keV to be released from their orbits. If a single photon of 50 keV strikes the metal surface, what is most likely to happen?

- (A) An electron with a kinetic energy of around 42 keV will leave the surface.
- (B) An electron will leave the surface, and the surface will be heated by the remaining 42 keV of photon energy.
- (C) Six electrons leave the surface, each using about 8 keV of the photon energy.
- (D) The photon, whose energy does not match the requirement of the electrons will not interact with the metal surface.

67. I noticed that water level in a clean glass straw dipped in a beaker of water was h units above the water level in the beaker, even without my sucking on it. Which of the following statements is **not true**?

- (A) The water will rise to a different height in a clean plastic straw of the same dimensions.
- (B) The water will rise higher than h units in a glass straw with smaller diameter.
- (C) The water rise will be lower than h units if the inner surface of the glass straw has a coating of oil.
- (D) The water rise in the glass straw will be $h/2$ if the height of water in the beaker is halved.

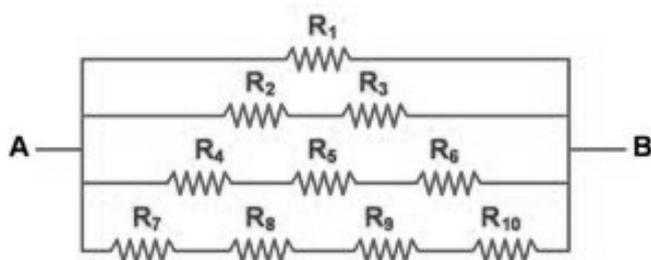
68. The approximate time taken for light to travel across the nucleus of an atom (order of magnitude only) is:

- (A) 10^{-20} s
- (B) 10^{-23} s
- (C) 10^{-26} s
- (D) 10^{-29} s

69. A measuring instrument has a main scale and its vernier scale. The main scale has 20 divisions in 1 cm. If the length of 25 divisions of the vernier scale exactly equals the length of 24 divisions of the main scale, the least count of the instrument is

- (A) 0.005 cm.
- (B) 0.05 cm.
- (C) 0.002 cm.
- (D) 0.0025 cm.

70. If every resistor in the given combination is 10Ω , the equivalent resistance across A and B is



- (A) 10Ω
- (B) 8.2Ω
- (C) 5Ω
- (D) 4.8Ω

HOMI BHABHA CENTRE FOR SCIENCE EDUCATION
TATA INSTITUTE OF FUNDAMENTAL RESEARCH

Entrance Test for Ph.D. Programme in Science Education – 2013

Section III: Critical Reasoning

Read the following instructions carefully.

- This section of the written test carries **60 marks** and is of **one hour** duration.
- This section of the question paper consists of 6 pages. It has three main questions of varying marks.
- The answers must be given on this question paper itself, in the space provided after each question. Do not exceed the space provided.
- Before you start answering, please check that you have written your Name and Roll Number in the space provided at the bottom of this page.
- At the end of one hour, please submit this question paper.

Name: _____

Roll Number:

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3. List three questions that you would like answered about the work done at HBCSE. [10 marks]

Question 1

Question 2

Question 3
