2023 MIT Science Bowl High School Invitational Round 4

TOSS UP

1) CHEMISTRY *Short Answer* Rank the following three compounds in terms of increasing lattice energy:

1) KCl
2) $MgCl_2$
3) NaCl

ANSWER: 1, 3, 2

BONUS

1) CHEMISTRY *Short Answer* Rank the following three elements in terms of increasing exothermicity of electron affinity:

1) Nitrogen
2) Oxygen
3) Sulfur

ANSWER: 1, 2, 3

TOSS UP

2) MATH *Multiple Choice* Which of the following conic section has an eccentricity of 2?

W) Parabola
X) Ellipse
Y) Circle
Z) Hyperbola

ANSWER: Z) Hyperbola

BONUS

2) MATH *Short Answer* What is the smallest three-digit prime number that evenly divides 1,000,343 (read: *one million three hundred forty three*)?

ANSWER: 107

TOSS UP

3) EARTH AND SPACE *Multiple Choice* In which of the following locations would one expect to observe the largest positive gravitational anomaly?

W) Middle of Chicxulub (*chick-sue-loob*) Crater
X) Along the Andes Mountains
Y) Middle of the Indian Ocean
Z) Along the Mid-Atlantic Ridge

ANSWER: X) Along the Andes Mountains

BONUS

3) EARTH AND SPACE *Short Answer* Identify all of the following statements which are true concerning the El Niño Southern Oscillation, or ENSO (*en-so*):

1) The thermocline deepens in the Western Pacific during a positive ENSO event
2) El Niño events tend to be stronger than La Niña events
3) The Humboldt current is stronger during a positive ENSO event

ANSWER: 1 and 2

TOSS UP

4) PHYSICS *Multiple Choice* Which of the following best describes how the relativistic energy of a massive object changes as a function of its velocity?

W) Zero at zero velocity, approaches a nonzero constant at high velocities
X) Zero at zero velocity, approaches infinity at high velocities
Y) Nonzero constant at zero velocity, approaches a nonzero constant at high velocities
Z) Nonzero constant at zero velocity, approaches infinity at high velocities

ANSWER: Z) Nonzero constant at zero velocity, approaches infinity at high velocities

BONUS

4) PHYSICS *Short Answer* Isaac is playing the violin when one of his strings breaks. The string can be modeled as an ideal spring which has been stretched from its rest length by 2 millimeters, so that it has a tension of 50 newtons. In joules, when the string breaks, how much energy is released?

ANSWER: 0.05

TOSS UP

5) BIOLOGY *Multiple Choice* Which of the following pair of terms correctly describes cellular respiration?

W) Anabolic and endergonic
X) Anabolic and exergonic
Y) Catabolic and endergonic
Z) Catabolic and exergonic

ANSWER: Z) Catabolic and exergonic

BONUS

5) BIOLOGY *Multiple Choice* Which of the following diseases can be characterized as protist-borne?

W) Malaria
X) Yellow fever
Y) Tuberculosis
Z) Autoimmune deficiency syndrome

ANSWER: W) Malaria

TOSS UP

6) ENERGY *Short Answer* The Spranger Lab at MIT studies how factors related to tumors, host tissues, and the environment affect how the immune system interacts with cancer cells. One focus of this lab is investigating how dendritic cells affect the tumor microenvironment. What is the name for the type of cells which include dendritic cells that process non-self antigens to activate an immune response?

ANSWER: Antigen-presenting cells (ACCEPT: APCs)

BONUS

6) ENERGY *Short Answer* Researchers in the Bartel Lab at MIT are studying the biochemical basis of micro RNA targeting efficiency in order to advance micro RNA target prediction. Micro RNAs are involved in what laboratory technique used to suppress expression in a targeted gene?

ANSWER: RNA interference (ACCEPT: RNAi)

TOSS UP

7) BIOLOGY *Short Answer* Which biome, found in the Mediterranean area, South Africa, and the western United States, includes characteristics such as fire-resistant shrubs and droughts in the summer?

ANSWER: Chaparral

BONUS

7) BIOLOGY *Multiple Choice* In which of the following parts of the human body would you find pseudostratified columnar epithelium?

W) Trachea
X) Epidermis
Y) Islets of Langerhans
Z) Ileum

ANSWER: W) Trachea

TOSS UP

8) PHYSICS *Short Answer* A candle is placed 3 meters away from a convex lens, which has a focal length of 2 meters. In meters, what is the distance of the image from the lens?

ANSWER: 6

BONUS

8) PHYSICS *Short Answer* MIT scientists shot X-rays towards a crystal surface. The smallest angle with the surface at which they observed the rays reflecting was at 30 degrees from the surface. In nanometers, what is the wavelength of the X-ray, if the distance between two adjacent atoms is 1 nanometer?

ANSWER: 1

TOSS UP

9) EARTH AND SPACE *Short Answer* What term refers to layered sedimentary formations formed by photosynthetic microorganisms that can contain evidence of life that goes back over 1 billion years?

ANSWER: Stromatolites (ACCEPT: Stromatoliths)

BONUS

9) EARTH AND SPACE *Multiple Choice* What type of pollution do hydroelectric power plants most commonly release into the environment?

W) Thermal pollution
X) Radioactive particulates
Y) Heavy metals
Z) Excess sediment due to high turbulence

ANSWER: W) Thermal pollution

TOSS UP

10) ENERGY *Short Answer* Researchers in the Kulik group at MIT are using computational modeling to investigate mechanisms of enzyme catalysis. What site on an enzyme is principally responsible for binding to its substrate and mediating catalysis?

ANSWER: Active site

BONUS

10) ENERGY *Short Answer* Researchers in the Freedman lab at MIT are working to chemically control spin lattices through relaxation methods to develop a basic two-state system. What is the name for this type of two-state system that acts as the unit of quantum information?

ANSWER: Qubit (ACCEPT: Quantum bit)

TOSS UP

11) MATH *Short Answer* Amelia has two coupons, one that provides 20% off and one that reduces the cost by 30 dollars. If Amelia can use both coupons in some order on an item that costs 100 dollars, what is the smallest possible final price in dollars?

ANSWER: 50

BONUS

11) MATH *Short Answer* Gilford's candy shop sells 3 different flavors of candies, and candies of the same flavor are indistinguishable. Alex visits Gilford's shop but can only buy 5 pieces of candy. How many different combinations of candies can Alex buy at Gilford's shop?

ANSWER: 21

TOSS UP

12) CHEMISTRY *Multiple Choice* Which of the following elements observes the strongest inert pair effect?

W) Phosphorus
X) Arsenic
Y) Antimony
Z) Bismuth

ANSWER: Z) Bismuth

BONUS

12) CHEMISTRY *Short Answer* Identify all of the following three salts that become more soluble at lower pH:

1) Calcium hydroxide
2) Rubidium cyanide
3) Mercury (II) Chloride (read: *mercury two chloride*)

ANSWER: 1 and 2

TOSS UP

13) EARTH AND SPACE *Multiple Choice* Over the course of a solar cycle, the distribution of sunspots tends to drift in what direction?

W) Towards the pole
X) Latitudinal dispersion increases
Y) Towards the equator
Z) Converges along 30 degrees north and south

ANSWER: Y) Towards the equator

BONUS

13) EARTH AND SPACE *Short Answer* Oscillating or nodding motion can be observed along the axis of rotation of the Earth. What term describes this type of motion that is driven by tidal forces which leads to variations in the speed of precession of the equinoxes over time?

ANSWER: Nutation

TOSS UP

14) PHYSICS *Short Answer* A charged particle is placed 1 meter away from an ideal electrical dipole. If the particle is moved 1 meter directly away from the dipole, by what factor does the force on the dipole change?

ANSWER: 1/8 (ACCEPT: 0.125)

BONUS

14) PHYSICS *Short Answer* An observer in an inertial reference frame sees two spaceships flying at each other, each at speed $3c/5$. In one spaceship's frame and in terms of c, what is the speed of the other spaceship?

ANSWER: $15c/17$

TOSS UP

15) ENERGY *Short Answer* Scientists at MIT's Plasma Science and Fusion Lab are studying the various challenges associated with achieving nuclear fusion. One popular approach for nuclear fusion is magnetic confinement, in which the fuel is heated to hundereds of millions of degrees. What state of matter is this fuel in?

ANSWER: Plasma

BONUS

15) ENERGY *Short Answer* Physicists in MIT's Jarillo-Herrero laboratory are studying twist angles in 2-D layered materials that introduce emergent properties. What type of pattern are the scientists studying in these materials?

ANSWER: Moiré (*mwa-ray*) patterns

TOSS UP

16) CHEMISTRY *Multiple Choice* Which of the following constants is obtained by dividing the ideal gas constant by Avogadro's number?

W) Faraday constant
X) Boltzmann constant
Y) Coulomb constant
Z) Rydberg constant

ANSWER: X) Boltzmann constant

BONUS

16) CHEMISTRY *Short Answer* Identify all of the following three reactions whose chemical driving force is enthalpy under standard conditions:

1) $Cl_2 + H_2 \longrightarrow 2\,HCl$ (read: *C-L-two plus H-two yields two H-C-L*)
2) $N_2 + 3\,H_2 \longrightarrow 2\,NH_3$ (read: *N-two plus three H-two yields two N-H-three*)
3) $O_2 \longrightarrow 2\,O$ (read: *O-two yields two O*)

ANSWER: 1 and 2

TOSS UP

17) MATH *Multiple Choice* x and y satisfy the equation $\log_{12}(x+y)+log_{12}(x-y) = 2$ (read: *log base 12 of open parentheses x plus y close parentheses plus log base 12 of open parentheses x minus y close parentheses equals 2*). Given that $y = 5$, what is the value of x?

W) $\sqrt{119}$
X) 13
Y) 14
Z) $\sqrt{197}$

ANSWER: X) 13

BONUS

17) MATH *Short Answer* What is the equation of the unique cubic polynomial $f(x)$ (read: *f of x*) with a leading coefficient of 1, a real root 2, and a complex root $1 + 3i$ (read: *one plus three i*)?

ANSWER: $x^3 - 4x^2 + 14x - 20$ (read: *x cubed minus four x squared plus fourteen x minus twenty*)

TOSS UP

18) BIOLOGY *Short Answer* What large group of photosynthetic protists possess glass-like cell walls composed of silicon dioxide and generate a significant amount of the oxygen produced on Earth?

ANSWER: Diatoms

BONUS

18) BIOLOGY *Short Answer* What molecule, often used in Western blotting procedures, coats the surface of proteins with a uniform negative charge?

ANSWER: SDS (ACCEPT: Sodium dodecyl sulfate)

TOSS UP

19) MATH *Short Answer* A four digit number has all distinct digits and its digits sum to 22. What is the largest possible value of the number?

ANSWER: 9850

BONUS

19) MATH *Multiple Choice* A square's area is increased by ten times its original area. To the nearest ten percent, by what percentage has its perimeter increased?

W) 230
X) 240
Y) 250
Z) 260

ANSWER: W) 230

TOSS UP

20) CHEMISTRY *Multiple Choice* Which of the following best describes the lewis structure of nitrogen dioxide?

W) Central nitrogen radical with two single bonds on each side
X) Central nitrogen radical with one single and one double bond
Y) Central oxygen radical with two single bonds on each side
Z) Central oxygen radical with one single and one double bond

ANSWER: X) Central nitrogen radical with one single and one double bond

BONUS

20) CHEMISTRY *Multiple Choice* Which of the following best describes how aqua regia dissolves gold?

W) Hydrochloric acid oxidizes gold and nitric acid stabilizes it by complexing the gold (I) (read: *gold one*) cation
X) Hydrochloric acid oxidizes gold and nitric acid stabilizes it by complexing the gold (III) cation
Y) Nitric acid oxidizes it and hydrochloric acid stabilizes it by complexing to the gold (I) cation
Z) Nitric acid oxidizes it and hydrochloric acid stabilizes it by complexing to the gold (III) cation

ANSWER: Z) Nitric acid oxidizes it and hydrochloric acid stabilizes it by complexing to the gold (III) cation

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TOSS UP

21) BIOLOGY *Multiple Choice* Which of the following hormones crosses the phospholipid bilayer to bind to a cytoplasmic receptor?

W) Aldosterone
X) Oxytocin
Y) Adrenocorticotropic hormone
Z) Luteinizing hormone

ANSWER: W) Aldosterone

BONUS

21) BIOLOGY *Short Answer* Identify all of the following three changes to a neuron that would make its resting membrane potential more negative:

1) Increasing membrane permeability to potassium
2) Increasing extracellular sodium concentration
3) Increasing extracellular chloride concentration

ANSWER: 1 and 3

TOSS UP

22) PHYSICS *Short Answer* As a result of having integer spin, what statistics do the distribution of phonons follow?

ANSWER: Bose-Einstein statistics

BONUS

22) PHYSICS *Short Answer* A double slit interference experiment is set up, so that light with wavelength 500 nanometers is passed through two slits separated by 0.1 millimeters. An interference pattern is formed on the wall 2 meters away. In meters, what is the separation between consecutive maxima of the interference pattern?

ANSWER: 0.01

TOSS UP

23) EARTH AND SPACE *Short Answer* Identify the following properties that accurately characterize hot dark matter:

1) Moves almost at the speed of light
2) Interacts with magnetic fields
3) Has mass

ANSWER: 1 and 3

BONUS

23) EARTH AND SPACE *Multiple Choice* Following the cannibalization of a dwarf galaxy, the dense former galactic core that remains gravitationally intact would most resemble what type of object?

W) Open cluster
X) Globular cluster
Y) X-ray binary
Z) O-B association

ANSWER: X) Globular cluster