

# 2025 MIT Science Bowl High School Invitational

## Round 3

### TOSS-UP

1) CHEMISTRY – *Multiple Choice* Which of the following bonds has the most ionic character?

- W) Potassium fluoride
- X) Potassium chloride
- Y) Rubidium fluoride
- Z) Rubidium chloride

ANSWER: Y) RUBIDIUM FLUORIDE

### BONUS

1) CHEMISTRY – *Short Answer* In a 1 molar solution of a weak acid, the concentration of hydronium is  $1 \times 10^{-6}$  (read: *one times ten to the negative sixth*). To the nearest whole number, what is the pKa of the acid?

ANSWER: 12

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### TOSS-UP

2) EARTH AND SPACE – *Short Answer* El Niño involves a weakening of what prevailing global wind belts that blow between 0 and 30 degrees latitude?

ANSWER: TRADE WINDS (ACCEPT: EASTERLIES)

### BONUS

2) EARTH AND SPACE – *Short Answer* Rank the following three structures in order of increasing crustal thickness: 1) Continental shield; 2) Oceanic crust; 3) Mountain.

ANSWER: 2, 1, 3

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### TOSS-UP

3) BIOLOGY – *Multiple Choice* The high temperatures in the denaturation step of PCR are intended to disrupt which type of bond that holds DNA strands together?

- W) Hydrogen
- X) Phosphodiester
- Y) Glycosidic
- Z) Amide

ANSWER: W) HYDROGEN

### BONUS

3) BIOLOGY – *Multiple Choice* Which of the following mutations in mRNA is silent?

- W) 5' - AUG - 3' (read: *5-prime AUG 3-prime*) to 5' - AAG - 3'
- X) 5' - UUA - 3' to 5' - UAA - 3'
- Y) 5' - GCA - 3' to 5' - GCAU - 3'
- Z) 5' - GGG - 3' to 5' - GGU - 3'

ANSWER: Z) 5' - GGG - 3' TO 5' - GGU - 3'

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### TOSS-UP

4) PHYSICS – *Multiple Choice* For an asteroid approaching our solar system, the total energy of the asteroid-sun system is greater than zero. What conic section does the asteroid's trajectory trace around the Sun?

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

ANSWER: Z) HYPERBOLA

### BONUS

4) PHYSICS – *Multiple Choice* Jacob places a positive charge some distance away from a isolated and conducting hollow sphere. Which of the following statements about Jacob's system must be true?

- W) The charge experiences a net repulsive force from the sphere
- X) The sphere has a net negative charge
- Y) No electric field exists inside the sphere
- Z) No electric field exists outside the sphere

ANSWER: Y) NO ELECTRIC FIELD EXISTS INSIDE THE SPHERE

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### TOSS-UP

5) MATH – *Short Answer* If  $3^x + 2^6 = 307$  (read: *quantity 3 to the power of x plus quantity 2 to the power of six equals 307*), what is  $x$ ?

ANSWER: 5

### BONUS

5) MATH – *Short Answer* A hexagonal pyramid has a height of 2 and a base of side length 3. What is the volume of the pyramid?

ANSWER:  $9\sqrt{3}$

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### TOSS-UP

6) ENERGY – *Short Answer* The White Lab recently published a study tracking the phosphorylation (read: *foss-for-ee-lay-shun*) of metabolic enzymes. What type of enzymes catalyze the phosphorylation of other proteins?

ANSWER: KINASES

### BONUS

6) ENERGY – *Short Answer* Scientists at MIT used deep learning to improve the runtime of physical simulations on periodic lattices. Identify all of the following three materials that have a long-range periodic lattice structure: 1) Graphene; 2) Quartz; 3) Glass.

ANSWER: 1 AND 2

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### TOSS-UP

7) BIOLOGY – *Multiple Choice* Which of the following traits is not characteristic of species adapted for living near carrying capacity?

- W) Few offspring
- X) Semelparous (read: *se-MEL-puh-ruhs*)
- Y) Type I survivorship curve
- Z) High parental care

ANSWER: X) SEMELPAROUS (READ: *SE-MEL-PUH-RUHS*)

### BONUS

7) BIOLOGY – *Short Answer* Identify all of the following three lab techniques that require NTPs: 1) Sanger sequencing; 2) PCR; 3) Western blot.

ANSWER: 1 AND 2

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### TOSS-UP

8) EARTH AND SPACE – *Multiple Choice* Which of the following statements regarding a glacier would be correct if a medial moraine is observed on the glacier?

- W) The glacier has at least one tributary glacier
- X) The glacier is a piedmont glacier
- Y) The glacier is melting rapidly
- Z) The glacier has experienced at least one icefall along its path

ANSWER: W) THE GLACIER HAS AT LEAST ONE TRIBUTARY GLACIER

### BONUS

8) EARTH AND SPACE – *Short Answer* Rank the following three soil horizons in order of lowest to highest concentration of organic material: 1) B; 2) O; 3) E.

ANSWER: 3, 1, 2

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### TOSS-UP

9) PHYSICS – *Multiple Choice* A 1-kilogram satellite has a circular orbit around Earth with radius  $r$ . In terms of  $r$ , what is the radius of the circular orbit of a 10-kilogram satellite around Earth?

- W)  $r/100$
- X)  $r/10$
- Y)  $r$
- Z)  $10r$

ANSWER: Y)  $r$

### BONUS

9) PHYSICS – *Multiple Choice* Planet A exerts a gravitational force of 1600 newtons on a satellite. If the mass of the satellite is 1 kilogram and its orbital radius is 25 meters, what is the satellite's orbital speed, in meters per second?

- W) 150
- X) 200
- Y) 300
- Z) 400

ANSWER: X) 200

### TOSS-UP

10) MATH – *Short Answer* A rectangle has area 56 and a side of length 7. If the lengths of both of the sides are increased by one, what is the area of the new rectangle?

ANSWER: 72

### BONUS

10) MATH – *Short Answer* For a function  $f$  and all reals  $x$ ,  $f(2x) = 2x^2 + 4x$  (read:  $f$  of  $2x$  equals  $2x$  squared plus  $4x$ ). What is  $f(1/2)$ ?

ANSWER: 9/8

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### TOSS-UP

11) CHEMISTRY – *Short Answer* Rank the following three ionic salts by increasing lattice energy: 1) Beryllium oxide; 2) Magnesium fluoride; 3) Lithium chloride.

ANSWER: 3, 2, 1

### BONUS

11) CHEMISTRY – *Multiple Choice* An aqueous solution of silver nitrate is added to a solution of sodium cyanide, forming the complex anion dicyanosilver. Which of the following best describes the signs of  $\Delta H$  and  $\Delta S$  for this process, respectively?

- W) Positive, positive
- X) Positive, negative
- Y) Negative, positive
- Z) Negative, negative

ANSWER: Z) NEGATIVE, NEGATIVE

### TOSS-UP

12) ENERGY – *Multiple Choice* Material scientists at the Li Group studied disordered rock salts. Which law of thermodynamics is responsible for rock salt configurations spontaneously disordering to increase their entropy?

- W) Zeroth
- X) First
- Y) Second
- Z) Third

ANSWER: Y) SECOND

### BONUS

12) ENERGY – *Multiple Choice* Chemists at the Quantum Measurement Group are studying mixed-valence compounds. Which of the following is a mixed-valence compound?

- W)  $\text{Al}_2\text{O}_3$  (read: *A L two O three*)
- X)  $\text{Fe}_3\text{O}_4$  (read: *F E three O four*)
- Y)  $\text{TiO}_2$  (read: *T i O two*)
- Z)  $\text{V}_2\text{O}_5$  (read: *V two O five*)

ANSWER: X)  $\text{Fe}_3\text{O}_4$  (READ: *F E THREE O FOUR*)

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### TOSS-UP

13) EARTH AND SPACE – *Multiple Choice* Where on an H-R diagram would a fully convective star be expected to be found?

- W) Top right
- X) Top left
- Y) Bottom right
- Z) Bottom left

ANSWER: Y) BOTTOM RIGHT

### BONUS

13) EARTH AND SPACE – *Short Answer* Jess lives on the Tropic of Cancer, at 23.5 degrees north. In degrees, what is the minimum declination a star must have for her to observe it as circumpolar?

ANSWER: 66.5

### TOSS-UP

14) CHEMISTRY – *Multiple Choice* Which of the following substances would react with sodium metal in a single replacement reaction?

- W) Potassium
- X) Chlorine gas
- Y) Water
- Z) Rubidium chloride

ANSWER: Y) WATER

### BONUS

14) CHEMISTRY – *Multiple Choice* Which of the following alkali metals has the lowest melting point?

- W) Rubidium
- X) Cesium
- Y) Sodium
- Z) Potassium

ANSWER: X) CESIUM

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### TOSS-UP

15) MATH – *Short Answer* A rectangular prism has sides of length 6, 8, and 24. What is the length of the space diagonal of this prism?

ANSWER: 26

### BONUS

15) MATH – *Short Answer* Identify all of the following length  $2\pi$  intervals over which the integral of the sine function is equal to 0: 1) Negative  $\pi$  to  $\pi$ ; 2) 0 to  $2\pi$ ; 3)  $\pi$  to  $3\pi$ .

ANSWER: ALL

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### TOSS-UP

16) PHYSICS – *Short Answer* When the angle of incidence of light at the interface between two media reaches the critical angle, what is the angle of refraction's measure in degrees?

ANSWER: 90

### BONUS

16) PHYSICS – *Short Answer* Two identical tanks are filled with equal masses of hydrogen and helium, respectively. If the tank containing helium is at half the absolute temperature of the tank containing hydrogen, then to one significant figure, what is the ratio of the pressure exerted by hydrogen to the pressure exerted by helium on their respective surroundings?

ANSWER: 4

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### TOSS-UP

17) ENERGY – *Short Answer* Scientists from the Earthquake Science Group cataloged the amount of energy released by earthquakes under New Zealand's North Island. What is the ratio of the energy released by a Richter magnitude 5.7 earthquake to that of a Richter magnitude 3.7 earthquake?

ANSWER: 1000

### BONUS

17) ENERGY – *Multiple Choice* Researchers in the Learning to Cure group are using AI tools to predict breast cancer risk from mammograms. Given a dataset of mammograms labelled with outcomes, which of the following categories would a system using this dataset fall under?

- W) Supervised learning
- X) Unsupervised learning
- Y) Reinforcement learning
- Z) Semi-supervised learning

ANSWER: W) SUPERVISED LEARNING

### TOSS-UP

18) BIOLOGY – *Multiple Choice* Retroviruses such as HIV use reverse transcriptase in their replication process. The genome of HIV is primarily made up of which of the following?

- W) single stranded DNA
- X) single stranded RNA
- Y) double stranded DNA
- Z) double stranded RNA

ANSWER: X) SINGLE STRANDED RNA

### BONUS

18) BIOLOGY – *Short Answer* Green smooth pea plants are dominant to yellow wrinkled pea plants. These two traits are completely linked. John crosses two true breeding smooth green and wrinkled yellow plants and self crosses the F1 generation. If a yellow offspring is picked among the F2 generation, what is the probability it is also smooth?

ANSWER: 0

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### TOSS-UP

19) ENERGY – *Short Answer* Researchers in MIT's Department of Urban Studies and Planning are applying LLMs to human mobility modeling in transportation. What specific attention-based neural network model architecture is used in most modern LLMs, including ChatGPT?

ANSWER: TRANSFORMER

### BONUS

19) ENERGY – *Multiple Choice* Physicists at the Quantum Measurement Group found that the resistivity of a europium-bismuth-selenide compound increases as temperature increases. Which of the following best characterizes this compound at room temperature?

- W) Conductor
- X) Insulator
- Y) Semiconductor
- Z) Superconductor

ANSWER: W) CONDUCTOR

### TOSS-UP

20) BIOLOGY – *Short Answer* Whereas a closed circulatory system pumps blood through closed vessels, an open circulatory system instead pumps what fluid through the hemocoel (read: *HEE-moh-seel*)?

ANSWER: HEMOLYMPH

### BONUS

20) BIOLOGY – *Short Answer* In the tracheal systems of insects, the trachea are kept open to the environment by rings made of what molecule?

ANSWER: CHITIN

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### TOSS-UP

21) MATH – *Short Answer* Tristan starts with \$50 and a fair six-sided die. He rolls the die each second, gaining one dollar if the result is prime and losing one dollar otherwise. He continues this until he either reaches \$100 or loses all his money. What is the probability that he loses all his money?

ANSWER: 1/2

### BONUS

21) MATH – *Short Answer* A relatively prime date is a date where the number of the month and the number of the day are relatively prime. Excluding January, which month has the most relatively prime days?

ANSWER: NOVEMBER

### TOSS-UP

22) PHYSICS – *Short Answer* A massless spring is connected to a block, which subsequently undergoes simple harmonic motion. What is the ratio of the kinetic energy to the potential energy of the system when the spring is extended to half of its maximum amplitude?

ANSWER: 3

### BONUS

22) PHYSICS – *Short Answer* A 12 kilohm (read: *kilo-ohm*) resistor is connected in parallel with a 3 kilohm resistor, and the two are connected in series to a 4 kilohm resistor. If an 8 volt potential difference is applied across the whole system, in volts, what is the voltage drop across the 12 kilohm resistor?

ANSWER: 3

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### TOSS-UP

23) EARTH AND SPACE – *Multiple Choice* Which of the following is not a piece of evidence supporting the hypothesis that Triton was captured by Neptune after formation?

- W) Triton's retrograde orbit
- X) Triton's similarity in composition to S-type asteroids
- Y) Triton's high orbital inclination
- Z) Nereid's (read: *near-e-ids*) high orbital eccentricity

ANSWER: X) TRITON'S SIMILARITY IN COMPOSITION TO S-TYPE ASTEROIDS

### BONUS

23) EARTH AND SPACE – *Multiple Choice* What energy transfer phenomena induces the formation of granules in the sun's photosphere?

- W) Conduction
- X) Convection
- Y) Radiation
- Z) Thermal diffusion

ANSWER: X) CONVECTION

### TOSS-UP

24) CHEMISTRY – *Multiple Choice* A 10-gram sample of which of the following salts would form the most pH neutral solution when dissolved in deionized water?

- W) Aluminum sulfate
- X) Potassium chloride
- Y) Sodium bicarbonate
- Z) Potassium fluoride

ANSWER: X) POTASSIUM CHLORIDE

### BONUS

24) CHEMISTRY – *Multiple Choice* After 20.5 grams of an unknown hydrocarbon are fully combusted in a sealed chamber, 66 grams of carbon dioxide are collected. Which of the following could be the molecular formula of the unknown hydrocarbon?

- W) C<sub>4</sub>H<sub>8</sub> (read: *C four H eight*)
- X) C<sub>5</sub>H<sub>8</sub>
- Y) C<sub>6</sub>H<sub>10</sub>
- Z) C<sub>7</sub>H<sub>10</sub>

ANSWER: Y) C<sub>6</sub>H<sub>10</sub>

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### TOSS-UP

25) BIOLOGY – *Multiple Choice* Spongocytes and choanocytes (read: *koh-ANN-oh-sites*) are cell types found in which of the following phyla of organisms?

- W) Ctenophora (read: *TEEN-oh-for-ah*)
- X) Cnidaria (read: *nye-DAIR-ee-ah*)
- Y) Porifera (read: *po-RIFF-uh-ruh*)
- Z) Cyclophoria (read: *sy-klo-FOR-ee-uh*)

ANSWER: Y) PORIFERA (READ: *PO-RIFF-UH-RUH*)

### BONUS

25) BIOLOGY – *Multiple Choice* Neurons 1 and 2 are both synapsed on neuron 3. When neuron 1 is activated, neuron 3 undergoes an action potential. When neuron 1 and 2 are both activated, neuron 3 doesn't undergo an action potential. Which of the following could be true of neuron 2's effects on neuron 3?

- W) The synapse between them is experiencing long term depression
- X) The synapse between them is experiencing long term potentiation
- Y) It increases the permeability of neuron 3 for sodium ions
- Z) It increases the permeability of neuron 3 for chloride ions

ANSWER: Z) IT INCREASES THE PERMEABILITY OF NEURON 3 FOR CHLORIDE IONS