

# 2020 MIT Science Bowl High School Invitational

## Round 3

### TOSS UP

1) CHEMISTRY *Multiple Choice* Which of the following compounds violates the octet rule?

- W)  $\text{NO}_2$
- X)  $\text{CH}_2\text{Cl}_2$
- Y)  $\text{S}_8$
- Z)  $\text{NCl}_3$

ANSWER: W)  $\text{NO}_2$

### BONUS

1) CHEMISTRY *Multiple Choice* The ideal gas law would best represent a gaseous system under which of the following conditions?

- W) High temperature, high pressure
- X) High temperature, low pressure
- Y) Low temperature, high pressure
- Z) Low temperature, low pressure

ANSWER: X) High temperature, low pressure

---

## **TOSS UP**

2) PHYSICS *Multiple Choice* Which of the following experiments was instrumental in discovering the quantization of electron spin?

- W) Michelson-Morley
- X) Stern-Gerlach
- Y) Hall
- Z) Blandford-Znajek (*BLAND-ford ZNAA-yek*)

ANSWER: X) Stern-Gerlach

## **BONUS**

2) PHYSICS *Multiple Choice* Which of the following is not a requirement for a fluid to be considered ideal?

- W) The fluid is irrotational
- X) The density of the fluid is constant throughout
- Y) The Reynolds number of the fluid is always 0
- Z) The fluid experiences no shear forces anywhere in its flow

ANSWER: Y) The Reynolds number of the fluid is always 0

---

## **TOSS UP**

3) EARTH AND SPACE *Multiple Choice* In which of the following scenarios would using a 500 millibar constant pressure chart be most useful?

- W) Predicting where low pressure systems may travel over time
- X) Determining the direction of wind at the surface
- Y) Determining the location of tornado vortices
- Z) Determining wind speeds at the surface

ANSWER: W) Predicting where low pressure systems may travel over time

## **BONUS**

3) EARTH AND SPACE *Short Answer* By name or number, identify all of the following three statements that are true of CO<sub>2</sub> measurements taken at Mauna Loa:

- 1) CO<sub>2</sub> concentrations peak at the end of winter
- 2) CO<sub>2</sub> concentrations have increased by more than 100% from pre-industrial levels
- 3) Increases in average CO<sub>2</sub> concentration have been roughly linear over time

ANSWER: 1 only

---

## **TOSS UP**

4) BIOLOGY *Multiple Choice* Which of the following hormones is synthesized from cholesterol?

- W) Epinephrine (*EH-pi-NEH-frinn*)
- X) Thyroxine
- Y) Aldosterone
- Z) Oxytocin

ANSWER: Y) Aldosterone

## **BONUS**

4) BIOLOGY *Short Answer* By name or number, identify all of the following four cytoskeletal elements that are primarily associated with the cleavage furrow formed in animal mitotic division.

- 1) Actin
- 2) Keratin
- 3) Myosin
- 4) Tubulin

ANSWER: 1 and 3

---

## **TOSS UP**

5) MATH *Short Answer* To the nearest integer, what is  $\log_3(7) \times \log_7(9)$  (read: *log base 3 of 7 times log base 7 of 9*)?

ANSWER: 2

## **BONUS**

5) MATH *Short Answer* If  $\log_8(32) = \log_x(3125)$  (read: *log base 8 of 32 equals log base x of 3125*), what is  $x$ ?

ANSWER: 125

---

## **TOSS UP**

6) ENERGY *Short Answer* Researchers in the Lodish group at MIT are studying erythropoiesis, the formation of red blood cells. By name or number, identify all of the following four organelles that are missing in red blood cells.

- 1) Nucleus
- 2) Ribosome
- 3) Cell membrane
- 4) Mitochondrion

ANSWER: 1 and 4

## **BONUS**

6) ENERGY *Multiple Choice* Researchers in the Lodish group are studying brown fat and white fat cells. Which of the following best describes a key feature of brown fat?

- W) Brown fat cells contain low levels of hemoglobin which white fat cells lack, coloring them brown
- X) Brown fat cells decouple their electron transport chain from ATP production, thus generating more heat
- Y) Brown fat cells comprise the majority of adipose tissue in the body
- Z) Brown fat helps cool down the body by acting as a sink for heat

ANSWER: X) Brown fat cells decouple their electron transport chain from ATP production, thus generating more heat

---

## **TOSS UP**

7) CHEMISTRY *Short Answer* By name or number, identify all of the following three things which can change the equilibrium constant of a reaction.

- 1) Changing the temperature
- 2) Removing products as they form
- 3) Adding more starting material to the reaction mixture

ANSWER: 1 only

## **BONUS**

7) CHEMISTRY *Short Answer* How many structural isomers are there for the compound C<sub>5</sub>H<sub>12</sub>?

ANSWER: 3

---

## **TOSS UP**

8) ENERGY *Short Answer* Researchers at the MIT Kavli Institute use observations of the 21-centimeter spectroscopic line in order to better understand the early universe. What molecular element is the source of the 21-centimeter spectroscopic line?

ANSWER: Hydrogen

## **BONUS**

8) ENERGY *Multiple Choice* Researchers at MIT's Research Laboratory for Electronics have been investigating novel methods of representing digital logic on the microscopic level. Which of the following circuit elements is used as the basis of all digital logic gates?

- W) Diode
- X) Transistor
- Y) Transformer
- Z) Rectifier

ANSWER: X) Transistor

---

## **TOSS UP**

9) BIOLOGY *Multiple Choice* Which of the following is NOT a short term physiological response of the human body to high altitude?

- W) Increased heart rate
- X) Decreased affinity of hemoglobin to oxygen
- Y) Increased mitochondria in aerobic tissues
- Z) Increased breathing rate and depth

ANSWER: Y) Increased mitochondria in aerobic tissues

## **BONUS**

9) BIOLOGY *Short Answer* Arrange the following 3 sites from first to last in order of a tRNA's path through a ribosome:

- 1) E site
- 2) P site
- 3) A site

ANSWER: 3, 2, 1

---

## **TOSS UP**

10) PHYSICS *Short Answer* A car starts from rest and accelerates at 10 meters per second squared. After 4 seconds, how far in meters has the car travelled?

ANSWER: 80 meters

## **BONUS**

10) PHYSICS *Multiple Choice* Which of the following colors would you expect to refract by the largest angle when passing through a prism?

- W) Red
- X) Yellow
- Y) Green
- Z) Violet

ANSWER: Z) Violet

---

## **TOSS UP**

11) EARTH AND SPACE *Short Answer* A star has a parallax angle of 0.1 arcseconds. How far away, in parsecs, is the star from the earth?

ANSWER: 10 parsecs

## **BONUS**

11) EARTH AND SPACE *Short Answer* Identify all of the following four minerals as being either silicates, carbonates, halides, or sulfates:

- 1) Quartz
- 2) Dolomite
- 3) Gypsum
- 4) Talc

ANSWER: 1) Silicate; 2) Carbonate; 3) Sulfate; 4) Silicate

---

## **TOSS UP**

12) MATH *Short Answer* In a standard deck of 52 cards, a straight flush is a set of 5 consecutive cards of the same suit, such as the 4, 5, 6, 7, and 8 of clubs. The Ace can be either the highest card or the lowest, but one may not “wrap around”—for instance, the Queen, King, Ace, 2, and 3 of spades do not constitute a straight flush. How many distinct straight flushes are there?

ANSWER: 40

## **BONUS**

12) MATH *Multiple Choice* How many ways are there to make change for \$9 using only \$1, \$2, and \$5 bills?

- W) 7
- X) 8
- Y) 9
- Z) 10

ANSWER: X) 8

---

## **TOSS UP**

13) BIOLOGY *Multiple Choice* Which of the following pH values best approximates the pH of a lysosome?

- W) 2
- X) 5
- Y) 8
- Z) 11

ANSWER: X) 5

## **BONUS**

13) BIOLOGY *Multiple Choice* Small molecule inhibitors of proteins associated with which of the following cellular sites will NOT inhibit mitosis?

- W) Microtubule plus end
- X) Microtubule minus end
- Y) Topoisomerase I (*toe-poe-eye-SAW-mer-aze one*) cleavage complex
- Z) Holliday junction

ANSWER: Z) Holliday junction

---

## TOSS UP

14) MATH *Short Answer* What is the term used to describe two lines in space which do not both lie in the same plane?

ANSWER: Skew (accept: agonic)

## BONUS

14) MATH *Multiple Choice* Let  $A$ ,  $B$ ,  $C$ , and  $D$  be the vertices of a regular tetrahedron with side length 12. The lines  $AB$  and  $CD$  are skew lines. What is the shortest distance between these lines?

- W)  $2\sqrt{5}$
- X) 6
- Y)  $4\sqrt{3}$
- Z)  $6\sqrt{2}$

ANSWER: Z)  $6\sqrt{2}$

---

## **TOSS UP**

15) EARTH AND SPACE *Multiple Choice* Which of the following lapse rates is needed to determine the altitude at which a cloud forms?

- W) Dry adiabatic and wet adiabatic
- X) Dry adiabatic and dew point
- Y) Dry adiabatic and environmental
- Z) Environmental and dew point

ANSWER: X) Dry adiabatic and dew point

## **BONUS**

15) EARTH AND SPACE *Multiple Choice* Which of the following is not a product of the proton-proton chain?

- W) Alpha particle
- X) Electron
- Y) Gamma ray
- Z) Neutrino

ANSWER: X) Electron

---

## **TOSS UP**

16) PHYSICS *Short Answer* What is the name of the maximum distance from a black hole that light can still escape from?

ANSWER: Schwarzschild radius

## **BONUS**

16) PHYSICS *Multiple Choice* A vat of molecular hydrogen is at a temperature of 400 kelvin. What temperature would a vat of oxygen molecules need to be at in order for the oxygen to have the same root-mean-square velocity as the hydrogen?

- W) 100 kelvin
- X) 400 kelvin
- Y) 1600 kelvin
- Z) 6400 kelvin

ANSWER: Z) 6400 kelvin

---

## **TOSS UP**

17) CHEMISTRY *Multiple Choice* Which of the following quantities increases as the concentration of the solute in a solution increases?

- W) Vapor pressure
- X) Boiling point
- Y) Freezing point
- Z) Ideality

ANSWER: X) Boiling point

## **BONUS**

17) CHEMISTRY *Multiple Choice* The point in a titration at which the indicator can be seen to change color is best described as which of the following:

- W) Endpoint
- X) Equivalence point
- Y) Normality point
- Z) Stoichiometric point

ANSWER: W) Endpoint

---

## **TOSS UP**

18) ENERGY *Short Answer* In September 2020, researchers at MIT, Cardiff University, and elsewhere reportedly found the spectral fingerprint of phosphine in the atmosphere of Venus, which they believe may be a sign of extraterrestrial life, a claim which other researchers have since contested. What is the oxidation state of phosphorus in the phosphine molecule?

ANSWER: -3

## **BONUS**

18) ENERGY *Short Answer* Researchers in the Gedik group at MIT are studying condensed matter physics, including the conductivity in various materials. One material they have been interested in is a single layer of carbon, which has exhibited distinctive conductive properties. What carbon material are they studying?

ANSWER: Graphene

---

## **TOSS UP**

19) EARTH AND SPACE *Multiple Choice* Which of the following is the name of the supermassive black hole at the center of the Milky Way?

- W) Sagittarius A\* (read: *A-star*)
- X) Cygnus X-1
- Y) M87-star
- Z) Crab Nebula

ANSWER: W) Sagittarius A\*

## **BONUS**

19) EARTH AND SPACE *Short Answer* By name or number, arrange the following 4 stellar spectral classes in order of decreasing surface temperature:

- 1) B
- 2) M
- 3) F
- 4) K

ANSWER: 1, 3, 4, 2

---

## **TOSS UP**

20) BIOLOGY *Multiple Choice* Which of the following behaviors is NOT characteristic of an *r*-selected species?

- W) High number of offspring per parent
- X) Type III (read: *type three*) population curve
- Y) Inverted population age pyramid
- Z) Low parental care

ANSWER: Y) Inverted population age pyramid

## **BONUS**

20) BIOLOGY *Short Answer* By name or number, identify all of the following four blood vessels that carry oxygenated blood in the human body:

- 1) Pulmonary (*PUL-mone-air-ee*) artery
- 2) Pulmonary vein
- 3) Aorta (*ay-OR-ta*)
- 4) Vena cava (*VEE-na CA-va*)

ANSWER: 2 and 3

---

## **TOSS UP**

21) PHYSICS *Short Answer* The result of a force being applied to an object over a period of time is a net change in its momentum, known as what?

ANSWER: Impulse

## **BONUS**

21) PHYSICS *Short Answer* A 10-centimeter-long solenoid with 100 windings carries 5 amperes of current. What is the magnetic field at the center of the solenoid, in teslas to one significant figure? Take the permeability of free space to be  $1.26 \times 10^{-6}$  henries per meter.

ANSWER:  $6 \times 10^{-3}$  teslas

---

## **TOSS UP**

22) MATH *Multiple Choice* Let  $\sigma$  be the standard deviation of a set of values. If each value in the set is tripled, what is the standard deviation of the new set?

- W)  $\sigma/3$
- X)  $\sigma$
- Y)  $3\sigma$
- Z)  $9\sigma$

ANSWER: Y)  $3\sigma$

---

## **BONUS**

22) MATH *Short Answer* Convert the value 1111 (read: *one one one one*) in base 8 into base 2.

ANSWER: 1001001001

---

## **TOSS UP**

23) CHEMISTRY *Multiple Choice* Which of the following salts has the highest lattice enthalpy?

- W) LiF
- X) NaCl
- Y) MgO
- Z) CdS

ANSWER: Y) MgO

## **BONUS**

23) CHEMISTRY *Short Answer* 2 grams of diatomic hydrogen and 16 grams of diatomic oxygen react together to form hydrogen peroxide. Assuming the reaction goes to completion, what is the mass of hydrogen peroxide formed to the nearest gram?

ANSWER: 17

---