

## TOSS-UP

1) Chemistry — *Short Answer* What is the term for a 50/50 mixture of enantiomers [*en-AN-tee-oh-murs*]?

ANSWER: RACEMIC MIXTURE (ACCEPT: RACEMATE)

## BONUS

1) Chemistry — *Short Answer* Identify all of the following three factors that can affect the rate of a chemical reaction: 1) Changing the temperature; 2) Changing the concentration of the reactants; 3) Adding a catalyst.

ANSWER: ALL

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## TOSS-UP

2) Earth and Space — *Short Answer* Proteus and Nereid [*Nair-ee-id*] are moons of what planet?

ANSWER: NEPTUNE

## BONUS

2) Earth and Space — *Short Answer* Early refractor telescopes were hindered by distortion because light rays of different colors are refracted to different focal points. This effect is known as what?

ANSWER: CHROMATIC ABERRATION

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## TOSS-UP

3) Energy — *Multiple Choice* Scientists at Argonne National Lab are developing solar cells made from perovskite [*purr-OFF-skite*] materials. Currently, most commercial solar cells are made from what material?

- W) Gallium [*GAL-ee-um*] arsenide
- X) Silicon
- Y) Cadmium telluride
- Z) Calcium titanate [*TIE-ten-ate*]

ANSWER: X) SILICON

## BONUS

3) Energy — *Short Answer* Scientists at the Thomas Jefferson National Accelerator Facility are studying pions [*PIE-ons*]. Pions are formed from what two flavors of quarks?

ANSWER: UP AND DOWN (ACCEPT IN EITHER ORDER)

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## TOSS-UP

4) Math — *Short Answer* In a geometric sequence with first two terms 1 and 3, what is the sum of the first 4 terms?

ANSWER: 40

## BONUS

4) Math — *Short Answer* What is the ratio of the volume of a sphere to that of a right circular cone whose base has the same radius as the sphere and whose height equals the diameter of the sphere?

ANSWER: 2 (ACCEPT: 2 TO 1)

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## TOSS-UP

5) Physics — *Multiple Choice* Which of the following physical quantities is equal to the rate of change of momentum?

- W) Energy
- X) Acceleration
- Y) Force
- Z) Torque [*tork*]

ANSWER: Y) FORCE

## BONUS

5) Physics — *Short Answer* A fixed amount of an ideal gas originally has a temperature of 300 kelvins, a volume of 20 liters, and a pressure of 1 atmosphere. If its pressure is increased to 3 atmospheres and its volume is decreased to 5 liters, then in kelvins, what will be the new temperature of the gas?

ANSWER: 225

## TOSS-UP

6) Biology — *Short Answer* Thermoregulation in mammals is primarily carried out by what part of the brain?

ANSWER: HYPOTHALAMUS

## BONUS

6) Biology — *Short Answer* From what primary germ layer does the lens of the mammalian eye develop?

ANSWER: ECTODERM

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## TOSS-UP

7) Chemistry — *Multiple Choice* Based on their bond-dissociation energies, which of the following bonds is strongest?

- W) C triple bond C
- X) H single bond F
- Y) N triple bond N
- Z) C triple bond N

ANSWER: Y) N TRIPLE BOND N

## BONUS

7) Chemistry — *Short Answer* Born-Haber cycles are an application of what law that states that a series of reactions can be combined to determine the enthalpy change of a reaction in question?

ANSWER: HESS'S LAW

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## TOSS-UP

8) Earth and Space — *Short Answer* Short-period comets originate beyond the orbit of Neptune in what region of the solar system?

ANSWER: KUIPER BELT

## BONUS

8) Earth and Space — *Multiple Choice* A star has a temperature of 2500 kelvins. Which of the following best categorizes the peak emission wavelength of the star?

- W) Yellow light
- X) Orange light
- Y) Red light
- Z) Infrared light

ANSWER: Z) INFRARED LIGHT

## TOSS-UP

9) Energy — *Multiple Choice* Scientists at the Thomas Jefferson National Accelerator Facility are studying a particle decay process that involves neutrino oscillations [*OSS-ih-LAY-shuns*]. Which of the following could physicists infer when they discovered neutrino oscillations?

- W) Neutrinos are sterile
- X) Neutrinos have mass
- Y) Neutrinos are baryons
- Z) Neutrinos are tachyons [*TAK-ee-ons*]

ANSWER: X) NEUTRINOS HAVE MASS

## BONUS

9) Energy — *Short Answer* Argonne National Lab scientists are using machine learning to understand the behavior of heat-resistant materials at very high temperatures. Place the following three materials in increasing order of melting point: 1) Stainless steel; 2) Alumina; 3) Cast iron.

ANSWER: 3, 1, 2

## TOSS-UP

10) Math — *Multiple Choice* Which of the following values is NOT in the range of  $f$  of  $x = e^x - 2$ ?

- W)  $-2$
- X)  $-1$
- Y)  $0$
- Z)  $1$

ANSWER: W)  $-2$

## BONUS

10) Math — *Short Answer* Two complex numbers have absolute values of  $5\sqrt{3}$  and  $2\sqrt{3}$ , and angles of  $263$  degrees and  $158$  degrees, respectively. What are the absolute value and the angle degree measure of their product?

ANSWER: ABSOLUTE VALUE =  $30$ ; ANGLE =  $61$  (do not accept:  $421$ )

## TOSS-UP

11) Physics — *Multiple Choice* Which of the following laws is most useful for calculating the electrical field generated by a stationary point charge at a particular distance?

- W) Coulomb's Law
- X) Biot-Savart [*BEE-oh-suh-VAR*] Law
- Y) Ampere's Law
- Z) Faraday's Law

ANSWER: W) COULOMB'S LAW

## BONUS

11) Physics — *Short Answer* Rank the following three substances in order of increasing speed of sound in that substance at STP: 1) Iron; 2) Sea water; 3) Air.

ANSWER: 3, 2, 1

## TOSS-UP

12) Biology — *Multiple Choice* Which of the following organisms is most likely to be a primary consumer in a lake ecosystem?

- W) Zooplankton [*ZOH-oh-plank-ton*]
- X) Cyanobacteria
- Y) Predatory fish
- Z) Detritus [*deh-TRY-tus*]-eating crayfish

ANSWER: W) ZOOPLANKTON

## BONUS

12) Biology — *Short Answer* Instead of lungs, many bony fish possess what homologous [*ha-MAWL-uh-gus*] gas-filled organ that allows for adjustment of buoyancy?

ANSWER: SWIM BLADDER (ACCEPT: GAS BLADDER, AIR BLADDER, FISH MAW)

## TOSS-UP

13) Chemistry — *Short Answer* What rule states that electrons will half-fill orbitals before pairing up?

ANSWER: HUND'S RULE

## BONUS

13) Chemistry — *Multiple Choice* Which of the following molecules contains carbon-carbon bonds with the most s-character?

W) Ethane

X) Ethene

Y) Ethyne [*ETH-eye-n*]

Z) Propane

ANSWER: Y) ETHYNE

## TOSS-UP

14) Earth and Space — *Short Answer* A brine pool containing sulfate and calcium is undergoing evaporation. What mineral will most likely result from this process?

ANSWER: GYPSUM

## BONUS

14) Earth and Space — *Short Answer* Denitrification [*dee-ny-trih-fih-KAY-shun*] by bacteria in very low oxygen environments can lead to the production of what potent greenhouse gas?

ANSWER: NITROUS OXIDE (ACCEPT: N<sub>2</sub>O, DINITROGEN MONOXIDE)

## TOSS-UP

15) Energy — *Short Answer* Scientists at Oak Ridge National Lab are fabricating silicon chips doped with vanadium [*vah-NAY-dee-um*] dioxide. What is the formal oxidation state of vanadium in vanadium dioxide?

ANSWER: +4 (ACCEPT: 4+, 4)

## BONUS

15) Energy — *Short Answer* Scientists supported by the Department of Energy are developing materials to serve as artificial connections between muscle and bone. What is the term for the natural version of these structures?

ANSWER: TENDONS



## TOSS-UP

16) Math — *Short Answer* What is the amplitude of a sinusoidal graph whose maximum value is 15 and minimum value is  $-7$ ?

ANSWER: 11

## BONUS

16) Math — *Short Answer* Let  $f$  of  $x$  be the fraction with numerator  $2x + 8$  and denominator  $x^2 + x - 12$ . How many horizontal asymptotes and how many vertical asymptotes does the graph of  $f$  have?

ANSWER: ONE HORIZONTAL AND ONE VERTICAL (ACCEPT: ONE OF EACH)

## TOSS-UP

17) Physics — *Short Answer* If the distance between two gravitationally-bound bodies is tripled, by what factor is the gravitational force between them multiplied?

ANSWER: 1/9

## BONUS

17) Physics — *Multiple Choice* Two electrons within the same orbital of an atom must have opposite spins. Which of the following principles most directly explains this phenomenon?

- W) Aufbau [*AUWF-bouw*] principle
- X) Uncertainty principle
- Y) Hund's rule
- Z) Pauli exclusion principle

ANSWER: Z) PAULI EXCLUSION PRINCIPLE

## TOSS-UP

18) Biology — *Short Answer* What type of transmembrane protein is typically involved in attaching epithelial [*eh-pih-THEEL-ee-ul*] cells to the extracellular matrix?

ANSWER: INTEGRIN

## BONUS

18) Biology — *Short Answer* Identify all of the following three organisms that are chondrichthyans [*kon-DRIK-thee-ans*]: 1) Sharks; 2) Rays; 3) Hagfish.

ANSWER: 1, 2