

HIGH SCHOOL - ROUND 15A

TOSS-UP

1) Chemistry – *Short Answer* A gas tank contains 82 liters of helium at 2.7 atmospheres of pressure. Given that the temperature of the tank is 27 degrees Celsius and the tank is filled with helium, then, to the nearest whole gram, how much helium is in the tank?

ANSWER: 36

BONUS

1) Chemistry – *Short Answer* A particular reaction doubles in rate when the temperature is raised from 50 kelvins to 100 kelvins. To the nearest hundred joules, what is the activation energy of this reaction?

ANSWER: 600

TOSS-UP

2) Physics – *Short Answer* Two resistors of 12 ohms each are connected in parallel to a 3-ampere current source. In watts, how much total power is dissipated by the circuit?

ANSWER: 54

BONUS

2) Physics – *Short Answer* Identify all of the following three physical quantities that are vectors: 1) Impulse; 2) Force; 3) Momentum.

ANSWER: ALL OF THEM

TOSS-UP

3) Earth and Space – *Multiple Choice* Which of the following best describes the mass of Ceres [*SEER-eez*] in terms of a percentage of the mass of our Moon?

- W) 0.001
- X) 1
- Y) 100
- Z) 200

ANSWER: X) 1

BONUS

3) Earth and Space – *Multiple Choice* A star is consistently observed to have a 1% dip in brightness lasting for 3 hours every 3 days. Which of the following is the best explanation of this phenomenon?

- W) The star is an intrinsic variable
- X) The star is rotating
- Y) The star has an exoplanet
- Z) The observation is distorted by parallax

ANSWER: Y) THE STAR HAS AN EXOPLANET

TOSS-UP

4) Math – *Multiple Choice* A and B are statements, and B is true. Which of the following is true regarding the statement " A implies B ?"

- W) It is true regardless of the truth value of A
- X) It is false regardless of the truth value of A
- Y) It is true only when A is true, and false otherwise
- Z) It is true only when A is false, and false otherwise

ANSWER: W) IT IS TRUE REGARDLESS OF THE TRUTH VALUE OF A

BONUS

4) Math – *Short Answer* Triangle ABC has all angles with integral degree measures, and the measure of angle A equals 7 times the measure of angle B . How many possible degree measures are there for angle C ?

ANSWER: 22

TOSS-UP

5) Biology – *Short Answer* What substance, which is produced by parietal [*pah-RYE-eh-t-ul*] cells in the stomach, is needed for the uptake of vitamin B12?

ANSWER: INTRINSIC FACTOR (ACCEPT: GASTRIC INTRINSIC FACTOR)

BONUS

5) Biology – *Short Answer* Identify all of the following three surface receptors whose synthesis depends on VDJ recombination: 1) Toll-like receptor; 2) T-cell receptor; 3) B-cell receptor.

ANSWER: 2, 3

TOSS-UP

6) Energy – *Multiple Choice* Department of Energy and Argonne National Lab researchers have recently found that termolecular [*ter-mo-lecular*] reactions may play a significant role in a number of processes. Why had chemists previously considered termolecular reactions to be insignificant?

- W) Termolecular reactions have high changes in entropy
- X) Termolecular reactions are usually endothermic
- Y) Termolecular reactions are forbidden by the Woodward-Hoffmann rules
- Z) Termolecular reactions are statistically unlikely to occur

ANSWER: Z) TERMOLECULAR REACTIONS ARE STATISTICALLY UNLIKELY TO OCCUR

BONUS

6) Energy – *Multiple Choice* DOE researchers recently detected the simultaneous arrival on Earth of the gravitational waves and the light emitted from a distant neutron star merger. This simultaneous arrival implies that, if a graviton particle exists, it must have a mass most similar to which of the following particles?

- W) Top quark
- X) Proton
- Y) Neutron
- Z) Photon

ANSWER: Z) PHOTON

TOSS-UP

7) Chemistry – *Short Answer* Arrange the following four diatomic molecules in order of increasing bond length: 1) N₂; 2) Cl₂; 3) F₂; 4) O₂.

ANSWER: 1, 4, 3, 2

BONUS

7) Chemistry – *Short Answer* Identify all of the following three diatomic species that have non-zero bond order: 1) H₂⁺; 2) H₂⁻; 3) H₂²⁻.

ANSWER: 1, 2

TOSS-UP

8) Physics – *Multiple Choice* Suppose a capacitor holds a charge Q and voltage V but is currently NOT connected to a voltage source. If a dielectric with dielectric constant 10 is inserted between the plates, then which of the following is TRUE?

- W) The voltage between the plates is multiplied by a factor of 10
- X) The voltage between the plates is multiplied by a factor of 1/10
- Y) The charge on the plates is multiplied by a factor of 10
- Z) The charge on the plates is multiplied by a factor of 1/10

ANSWER: X) THE VOLTAGE BETWEEN THE PLATES IS MULTIPLIED BY A FACTOR OF 1/10

BONUS

8) Physics – *Short Answer* Identify all of the following three observations that are consistent with the particle model of light, but not the wave model of light: 1) Compton scattering; 2) Photoelectric effect; 3) Diffraction.

ANSWER: 1, 2

TOSS-UP

9) Math – *Short Answer* What is the dot product of the vectors $3\mathbf{i} - 2\mathbf{j} + \mathbf{k}$ and $4\mathbf{i} - \mathbf{j}$?

ANSWER: 14

BONUS

9) Math – *Short Answer* In a particular year, if June 6 is on a Tuesday, on what day of the week is December 7?

ANSWER: THURSDAY

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**TOSS-UP**

10) Biology – *Short Answer* What stage of embryonic development that follows the morula [**MOOR-yoo-lah**] is characterized as a fluid-filled sphere?

ANSWER: BLASTULA

**BONUS**

10) Biology – *Short Answer* Identify all of the following three features that all chordates possess at some point in their development: 1) Vertebral column; 2) Pharyngeal [**fair-in-JEE-ul**] slits; 3) Post-anal tail.

ANSWER: 2, 3

### TOSS-UP

11) Energy – *Multiple Choice* The Spallation Neutron Source at Oak Ridge National Lab is used to study material properties. Which of the following best describes neutron spallation?

- W) High-energy protons collide with a nucleus, which then emits neutrons
- X) High-energy neutrons collide with a nucleus, which then emits protons
- Y) Low-energy neutrons are absorbed by a nucleus, which splits and emits neutrons
- Z) High-energy neutrons are absorbed by a nucleus, which splits and emits neutrons

ANSWER: W) HIGH-ENERGY PROTONS COLLIDE WITH A NUCLEUS, WHICH THEN EMITS NEUTRONS

### BONUS

11) Energy – *Short Answer* Scientists at SLAC National Accelerator Lab are studying the properties of a calcium titanate [*TIE-ten-ate*] mineral that may eventually outperform silicon-based solar cells. What is the common name of this mineral?

ANSWER: PEROVSKITE

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### TOSS-UP

12) Earth and Space – *Multiple Choice* On a map of the magnetic anomalies recorded in the Earth's oceanic crust, you will see a series of bands aligned roughly parallel to the mid-ocean spreading centers representing reversals in the Earth's magnetic field. A contour line that separates two magnetic anomalies is which of the following?

- W) Isochron [*EYE-soh-krawn*]
- X) Isochor [*EYE-soh-koar*]
- Y) Isostasy [*eye-SAW-stah-see*]
- Z) Isocline

ANSWER: W) ISOCHRON

### BONUS

12) Earth and Space – *Multiple Choice* Seismologists believe that Earth's inner core rotates faster than the rest of the planet. What evidence do they cite?

- W) The fastest route for s-waves is shifting eastward over time
- X) The fastest route for s-waves is shifting westward over time
- Y) The fastest route for p-waves is shifting eastward over time
- Z) The fastest route for p-waves is shifting westward over time

ANSWER: Y) THE FASTEST ROUTE FOR P-WAVES IS SHIFTING EASTWARD OVER TIME

### TOSS-UP

13) Biology – *Multiple Choice* Which of the following diseases is caused by an apicomplexan [*appee-com-PLEX-en*]?

- W) Tuberculosis
- X) Malaria
- Y) Chagas [*SHAH-gus*] disease
- Z) AIDS

ANSWER: X) MALARIA

### BONUS

13) Biology – *Short Answer* D5W is a solution found in IV bags that is 5% glucose by weight. Given that the molar mass of glucose is 180 grams per mole, then expressed in milliosmoles [*mill-ee-OZ-moles*] per liter to one significant figure, what is the osmolarity [*oz-mow-LAIR-it-ee*] of D5W?

ANSWER: 300

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### TOSS-UP

14) Physics – *Short Answer* A light wave is propagating along the  $x$ -axis in the positive direction. If the electric field is currently oriented toward the positive  $z$ -axis, then expressing your answer as a sign and an axis, which way is the magnetic field oriented?

ANSWER: NEGATIVE  $y$ -AXIS

### BONUS

14) Physics – *Multiple Choice* For real gases, the difference between their molar heat capacities at constant pressure and at constant volume is equal to the ideal gas constant plus or minus some deviation. For which of the following gases is this deviation the largest?

- W) Helium
- X) Argon
- Y) Carbon monoxide
- Z) Carbon dioxide

ANSWER: Z) CARBON DIOXIDE

### TOSS-UP

15) Chemistry – *Multiple Choice* According to VSEPR [*VESS-pur*] theory, which of the following statements is TRUE concerning the trigonal [*TRIH-gunul*] bipyramidal [*BYE-peer-ah-MID-ul*] geometry?

- W) The molecular geometry of BrF<sub>5</sub> is trigonal bipyramidal
- X) Lone pairs occupy equatorial positions
- Y) The associated central-atom hybridization is d<sup>2</sup>sp<sup>3</sup>
- Z) The electron-pair geometry of CCl<sub>4</sub> is trigonal bipyramidal

ANSWER: X) LONE PAIRS OCCUPY EQUATORIAL POSITIONS

### BONUS

15) Chemistry – *Short Answer* Identify all of the following three statements that describe the dimerization [*dye-mur-ih-ZAY-shun*] reaction of butadiene [*byoo-tah-DYE-een*]: 1) It is first-order; 2) It is entropically [*en-TRAW-pik-ah-lee*] favored; 3) The half-life increases over time.

ANSWER: 3

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### TOSS-UP

16) Earth and Space – *Multiple Choice* Which of the following statements is true of main sequence stars?

- W) Class A stars are the hottest
- X) Less-massive stars have longer lifetimes than more-massive stars
- Y) Less-massive stars have higher luminosities than more-massive stars
- Z) Red supergiants are the coolest main-sequence stars

ANSWER: X) LESS-MASSIVE STARS HAVE LONGER LIFETIMES THAN MORE-MASSIVE STARS

### BONUS

16) Earth and Space – *Short Answer* A doublet of strong yellow D lines in the spectrum of the Sun are absorption lines stemming from what element?

ANSWER: SODIUM



### TOSS-UP

17) Math – *Short Answer* What is the limit as  $x$  approaches one of the fraction with numerator  $x^2 - 9$  and denominator  $x^3 - 27$ ?

ANSWER: 4/13

### BONUS

17) Math – *Short Answer* A right circular cone with height 8 and radius 6 is sliced halfway along its height to form a frustum. What is the lateral surface area of the frustum?

ANSWER:  $45\pi$

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### TOSS-UP

18) Energy – *Short Answer* Scientists at Los Alamos National Lab are studying upwelling in the Southern Ocean using a combination of seawater measurements and modeling. In particular, they identified five major upwelling hotspots associated with undersea topographic features in the path of what ocean current, the largest and strongest in the globe?

ANSWER: ANTARCTIC CIRCUMPOLAR CURRENT (ACCEPT: ACC)

### BONUS

18) Energy – *Short Answer* The ICARUS [*IH-kah-rus*] detector has been moved to the Fermi National Accelerator Lab for further neutrino experiments. This detector is filled with argon that, upon interaction with a neutrino, becomes what element?

ANSWER: POTASSIUM (ACCEPT: K)

### TOSS-UP

19) Earth and Space – *Short Answer* What chemical element is in the chemical formula for dolomite, but not that for calcite?

ANSWER: MAGNESIUM (ACCEPT: Mg)

### BONUS

19) Earth and Space – *Short Answer* An erratic, such as Big Rock in Alberta, Canada, is a large boulder whose geology differs significantly from that of its current location. What carried this erratic to its current location?

ANSWER: GLACIER (ACCEPT: ICE, ICE SHEET)

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### TOSS-UP

20) Chemistry – *Multiple Choice* When comparing carbon-13 NMR to proton NMR, which of the following best explains why one rarely sees coupling between carbon nuclei in C13 NMR?

- W) Carbon-13 nuclei do not magnetically couple with one another
- X) Carbon-13 nuclei have no net magnetic moment
- Y) Carbon-13 coupling is usually compensated for with the NMR probe
- Z) It is rare for any given molecule to have more than one carbon-13 atom

ANSWER: Z) IT IS RARE FOR ANY GIVEN MOLECULE TO HAVE MORE THAN ONE CARBON-13 ATOM

### BONUS

20) Chemistry – *Multiple Choice* For which of the following reactions does  $K_p$ , the pressure equilibrium constant, equal  $K_c$ , the concentration equilibrium constant?

- W) Hydrogen (gas) + chlorine (gas) yields 2 hydrogen chloride (gas)
- X) 2 hydrogen (gas) + oxygen (gas) yields 2 water (gas)
- Y) Nitrogen (gas) + 2 oxygen (gas) yields 2 nitrogen dioxide (gas)
- Z) Dinitrogen tetroxide (gas) yields 2 nitrogen dioxide (gas)

ANSWER: W) HYDROGEN (GAS) + CHLORINE (GAS) YIELDS 2 HYDROGEN CHLORIDE (GAS)

### TOSS-UP

21) Physics – *Short Answer* Which of Maxwell’s equations directly enforces the postulate that magnetic monopoles do not exist?

ANSWER: GAUSS’S LAW FOR MAGNETISM (DO NOT ACCEPT: GAUSS’S LAW)

### BONUS

21) Physics – *Short Answer* An object is undergoing one-dimensional motion at time  $t = 0$ . If its velocity equals 3 times the exponential of  $-2t$ , then, as times increases, what value does the total displacement of the object approach?

ANSWER:  $3/2$  (ACCEPT: 1.5,  $1\frac{1}{2}$ )

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### TOSS-UP

22) Math – *Short Answer* What is the sum of the zeroes of the polynomial  $2x^3 + 11x^2 + 2x - 16$ ?

ANSWER:  $-11/2$  (ACCEPT  $-5.5$ ,  $-5\frac{1}{2}$ )

### BONUS

22) Math – *Short Answer* What is the largest prime factor of the quantity  $5^{2016} + 5^{2017} + 5^{2018} + 5^{2019}$ ?

ANSWER: 13

### TOSS-UP

23) Biology – *Short Answer* The synapsids and the reptiles were able to adapt to life on land due to what key evolutionary innovation?

ANSWER: AMNIOTIC EGG

### BONUS

23) Biology – *Short Answer* Identify all of the following three classes of chordates [**KOR-dates**] that possess vertebrae: 1) Myxini; 2) Reptilia; 3) Cephalochordata [**sef-ah-loh-kor-DAH-tah**].

ANSWER: 1, 2