

HIGH SCHOOL - ROUND 15A

TOSS-UP

1) Chemistry – *Multiple Choice* Adding which of the following solutes to hexane would form a solution that most closely obeys Raoult's [*rah-OOLZ*] law?

- W) Acetone
- X) Benzene
- Y) Pentane
- Z) Ethanol

ANSWER: Y) PENTANE

BONUS

1) Chemistry – *Multiple Choice* A student isolates a natural product from a tropical frog and takes a proton NMR in deuterated chloroform. They notice that there is a sharp peak at 10.5 parts per million in the compound. This suggests the presence of what functional group?

- W) Nitrile
- X) Alcohol
- Y) Aldehyde
- Z) Ether

ANSWER: Y) ALDEHYDE

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### TOSS-UP

2) Physics – *Short Answer* In classical electromagnetic theory, the speed of light in a vacuum can be written exactly in terms of the permittivity of free space and what other fundamental physical constant?

ANSWER: PERMEABILITY OF FREE SPACE (ACCEPT: PERMEABILITY, MU-0, MU-NAUGHT)

### BONUS

2) Physics – *Short Answer* Identify all of the following three statements that are true regarding the relationship between momentum and energy: 1) For a photon, if momentum is doubled, kinetic energy is doubled; 2) For a neutron, if momentum is doubled, kinetic energy is doubled; 3) For an alpha particle, if momentum is doubled, kinetic energy is doubled.

ANSWER: 1

**TOSS-UP**

3) Earth and Space – *Multiple Choice* An igneous [*IG-nee-us*] rock sample is characterized as being composed of crystals of olivine, calcium-rich plagioclase, and augite, and has a phaneritic [*fan-er-IT-ik*] texture. Which of the following four rocks is it?

- W) Basalt [*bah-SALT*]
- X) Andesite
- Y) Gabbro
- Z) Granite

ANSWER: Y) GABBRO

**BONUS**

3) Earth and Space – *Multiple Choice* You are mapping a flat erosional surface of an anticline fold in which no rock layers have been overturned. Which of the following describes the change in age of the rock layers in the anticline as one walks from the hinge to the limb?

- W) The layers get older
- X) The layers get younger
- Y) The age of the layers is constant
- Z) Relative age cannot be determined

ANSWER: X) THE LAYERS GET YOUNGER



**TOSS-UP**

4) Math – *Short Answer* What is the partial derivative with respect to  $x$  of the expression  $x^3y^2$ ?

ANSWER:  $3x^2y^2$

**BONUS**

4) Math – *Short Answer* Teams A and B meet in a best-of-three series. If Team A wins any given game with probability  $3/5$ , what is the probability that Team A wins the series?

ANSWER:  $81/125$  (ACCEPT: 0.648, 64.8%)

**TOSS-UP**

5) Biology – *Short Answer* The Weddell seal is able to stay underwater for extraordinarily long periods of time due its ability to store twice as much oxygen per kilogram of body mass than humans. This ability is due to the seal having a high concentration of what protein in its muscles?

ANSWER: MYOGLOBIN

**BONUS**

5) Biology – *Multiple Choice* Glycosylphosphatidylinositol [*glue-koh-sil-faws-fah-tydil-in-AW-sih-tall*] would likely be found covalently bound to what type of protein?

- W) Transmembrane
- X) Cytosolic [*SY-tuh-soll-ik*]
- Y) Peripheral membrane
- Z) Lysosomal [*lye-soh-SOH-mul*]

ANSWER: Y) PERIPHERAL MEMBRANE

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TOSS-UP

6) Energy – *Multiple Choice* To produce better containment vessels for commercial fusion power, scientists at Oak Ridge National Lab are working with what material that has the highest melting point of all metals?

- W) Tungsten
- X) Nickel
- Y) Chromium
- Z) Titanium

ANSWER: W) TUNGSTEN

BONUS

6) Energy – *Short Answer* Lawrence Berkeley Lab scientists helped build a new LCLS-II undulator, an important component of a proposed free-electron laser. Identify all of the following three statements that are true of this proposed laser: 1) It can be used to determine the structure of a crystallized protein; 2) It uses a crystalline lasing medium; 3) It can only produce light in the x-ray range.

ANSWER: 1

TOSS-UP

7) Chemistry – *Multiple Choice* Atom A possesses atomic orbitals that are slightly lower in energy than those of atom B. Which of the following is true of a bond between atoms A and B?

- W) It is ionic
- X) It is dative
- Y) It is nonpolar covalent [*koh-VAY-lent*]
- Z) It is polar covalent

ANSWER: Z) IT IS POLAR COVALENT

BONUS

7) Chemistry – *Multiple Choice* A carboxylic [*CAR-box-IHL-ik*] acid is stirred in a large excess of ethanol in the presence of a sulfuric acid catalyst. What functional group will this reaction form?

- W) Ester
- X) Amide [*AM-ide*]
- Y) Acid anhydride [*an-HIGH-dried*]
- Z) Acid chloride

ANSWER: W) ESTER

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**TOSS-UP**

8) Physics – *Short Answer* A guitar string is plucked, producing the single A5 tone at 880 hertz. To two significant figures and in milliseconds, what is the period of vibration of this string?

ANSWER: 1.1

**BONUS**

8) Physics – *Short Answer* A cylindrical rod with radius 25 centimeters increases in length by 1 part per million after being subjected to 1000 newtons of tension. Expressed in pascals and in scientific notation to one significant figure, what is the Young's modulus of this rod?

ANSWER: 5 TIMES 10<sup>9</sup>

### TOSS-UP

9) Math – *Short Answer* The end of a pendulum swings through an arc 4 feet long when the string swings through an angle of 0.8 radians. In feet, what is the length of the pendulum?

ANSWER: 5

### BONUS

9) Math – *Short Answer* What is the distance between the two points with polar coordinates  $r = 4$  and  $\theta = 120^\circ$ , and  $r = 6$  and  $\theta = 0^\circ$ ?

ANSWER:  $2\sqrt{19}$

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TOSS-UP

10) Biology – *Short Answer* Which of the three meninges [*meh-NIN-jeez*] of the brain is closest to the cerebral [*seh-REE-brul*] cortex?

ANSWER: PIA MATER

BONUS

10) Biology – *Short Answer* In ethanol fermentation, what molecule is formed via the decarboxylation [*dee-car-box-ill-AY-shun*] of pyruvate [*pie-ROO-vate*]?

ANSWER: ACETALDEHYDE (ACCEPT: ETHANAL, ETHYL ALDEHYDE, ACETYL ALDEHYDE)

TOSS-UP

11) Energy – *Multiple Choice* When Oak Ridge National Lab physicists use the term "doubly magic," it describes atomic nuclei [*NEW-klee-eye*] that have greater stability than their neighbors due to having shells that are fully occupied by both protons and neutrons. What nuclear property is maximized to create this effect?

- W) Neutron degeneracy [*dee-JEN-er-ah-see*] pressure
- X) Quantum spin
- Y) Electron-degeneracy pressure
- Z) Nucleon binding energy

ANSWER: Z) NUCLEON BINDING ENERGY

BONUS

11) Energy – *Multiple Choice* Researchers at Argonne National Lab are developing smart materials that can self-assemble and break down in response to external stimuli. They recently demonstrated self-assembly of nickel microparticles in the presence of what?

- W) Changing electrical field
- X) Changing magnetic field
- Y) Changing temperature
- Z) Changing particle concentration

ANSWER: X) CHANGING MAGNETIC FIELD

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**TOSS-UP**

12) Earth and Space – *Short Answer* For how many planets in the solar system is hydrogen the most abundant atmospheric gas?

ANSWER: FOUR

**BONUS**

12) Earth and Space – *Short Answer* An alien astronomer is observing our Sun as a flat disk with a temperature of 5800 kelvins when Jupiter passes in front of it. Given that the Sun has a radius of approximately 430,000 miles and Jupiter has a radius of approximately 43,000 miles and that Jupiter contributes negligible brightness to the system, then, to one significant figure, by what percentage does the brightness of the disk drop when Jupiter passes in front of the Sun?

ANSWER: 1

**TOSS-UP**

13) Biology – *Multiple Choice* Most angiosperm [*AN-jee-oh-sperms*] species can be classified in which of the following clades?

- W) Basal [*BAY-zul*]
- X) Magnoliids [*mag-NO-lee-idz*]
- Y) Monocots
- Z) Eudicots [*YOU-dih-kawts*]

ANSWER: Z) EUDICOTS

**BONUS**

13) Biology – *Multiple Choice* Which of the following hormones is primarily responsible for maintaining pregnancy in most mammalian species?

- W) Estrogen
- X) Lutenizing hormone
- Y) Progesterone
- Z) Prostaglandin [*PRAW-stah-glan-din*]

ANSWER: Y) PROGESTERONE

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TOSS-UP

14) Physics – *Multiple Choice* The liquid-drop model of the nucleus was originally proposed based on what observation?

- W) Rutherford gold-foil experiment
- X) All nuclei [*NEW-klee-eye*] have similar densities
- Y) Emission lines vary between elements
- Z) Millikan oil-drop experiment

ANSWER: X) ALL NUCLEI HAVE SIMILAR DENSITIES

BONUS

14) Physics – *Short Answer* A square surface with side length 3 meters is placed in a constant magnetic field of 2 teslas such that the normal to the surface forms a 45-degree angle with the field lines. In webers [*WEH-burz*] to the nearest whole number, what is the magnetic flux through the surface?

ANSWER: 13

TOSS-UP

15) Chemistry – *Multiple Choice* Which of the following carboxylic [**CAR-box-IHL-ik**] acid derivatives would be most reactive with a nucleophile [**NU-klee-oh-file**]?

- W) Amide [**AM-ide**]
- X) Acid chloride
- Y) Ester
- Z) Acid anhydride [**an-HIGH-dried**]

ANSWER: X) ACID CHLORIDE

BONUS

15) Chemistry – *Multiple Choice* Methylamine [**meh-thil-ah-MEEN**] reacts with 1-bromobutane [**one-broh-mo-BYOO-tane**] by donating electrons into what orbital of the carbon at the one position of bromobutane?

- W) C-C sigma bonding orbital
- X) C-C sigma antibonding orbital
- Y) C-Br sigma bonding orbital
- Z) C-Br sigma antibonding orbital

ANSWER: Z) C-Br SIGMA ANTIBONDING ORBITAL

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### TOSS-UP

16) Earth and Space – *Multiple Choice* What object may be formed by the collision of two galaxies, each containing a large black hole at the core?

- W) Quasar
- X) Pulsar
- Y) Neutron star
- Z) Supercluster

ANSWER: W) QUASAR

### BONUS

16) Earth and Space – *Short Answer* Place the following three Galilean satellites of Jupiter in increasing order of distance from Jupiter: 1) Europa; 2) Ganymede [**GAN-ih-meed**]; 3) Io [**EYE-oh**].

ANSWER: 3, 1, 2



**TOSS-UP**

17) Math – *Short Answer* What is the integer part of the log base 5 of 1000?

ANSWER: 4

**BONUS**

17) Math – *Short Answer* What is the area of an equilateral triangle whose circumcircle has a radius of 6?

ANSWER:  $27\sqrt{3}$

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TOSS-UP

18) Energy – *Short Answer* Due to environmental concerns with lead perovskites [*purr-OFF-skites*] as solar-cell materials, researchers at Ames Lab are studying what same-row, period 6 metal as an alternative thin-film material?

ANSWER: BISMUTH (ACCEPT: BI)

BONUS

18) Energy – *Multiple Choice* Plutonium Uranium Redox Extraction, or PUREX, is a standard worldwide method for doing which of the following?

- W) Achieving criticality in a reactor
- X) Poisoning a nuclear reactor
- Y) Reprocessing nuclear fuel
- Z) Mining uranium

ANSWER: Y) REPROCESSING NUCLEAR FUEL

TOSS-UP

19) Earth and Space – *Short Answer* Desert deflation will eventually cause the surface to be covered by rock fragments that are larger than sand. What is the term for this layer of coarse materials?

ANSWER: DESERT PAVEMENT

BONUS

19) Earth and Space – *Short Answer* Identify all of the following three statements that are true of earthquake waves: 1) A P-wave shadow zone exists because P waves cannot travel through the liquid outer core; 2) The P-wave shadow zone is smaller in area than the S-wave shadow zone; 3) An S-wave shadow zone exists because S waves cannot travel through the liquid outer core.

ANSWER: 2 AND 3

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### TOSS-UP

20) Chemistry – *Short Answer* A common reaction pathway in the liver for the detoxification of primary alcohols is to oxidize them to what functional group before oxidizing them to carboxylic [**CAR-box-IHL-ik**] acids?

ANSWER: ALDEHYDE

### BONUS

20) Chemistry – *Short Answer* A student is asked to identify a solution based only on color, given that it is a cobalt solution with either cyanide, water, fluorine, or chlorine as the ligand [**LIIH-gund**]. Which of these ligands would result in the complex absorbing the shortest wavelength light?

ANSWER: CYANIDE

**TOSS-UP**

21) Physics – *Short Answer* A concave mirror has a radius of curvature of 54 centimeters. In centimeters, what is its focal length?

ANSWER: 27

**BONUS**

21) Physics – *Short Answer* Identify all of the following three statements that are true regarding gas thermodynamics: 1) The ideal gas constant is equal to the Boltzmann constant multiplied by Avogadro's number; 2) At the same temperature, the atoms in xenon [*ZEE-non*] will have a higher root-mean-square velocity than those of helium; 3) The Boltzmann constant can be expressed with the same units as entropy [*EN-troh-pee*].

ANSWER: 1 AND 3

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TOSS-UP

22) Math – *Short Answer* The point (3, -5) is reflected through the x -axis, with the result then translated 4 units down. What are the coordinates of the final image?

ANSWER: (3, 1) (ACCEPT: $x = 3$ AND $y = 1$)

BONUS

22) Math – *Short Answer* What is the sum of the first 6 terms in the increasing geometric sequence with first term 4 and third term 36?

ANSWER: 1456

TOSS-UP

23) Biology – *Short Answer* A 19th-century Danish scientist classified bacteria based on the ability of their cell walls to retain crystal violet, which is due to the abundance of what polymer?

ANSWER: PEPTIDOGLYCAN [*peptihdo-GLY-can*]

BONUS

23) Biology – *Short Answer* Parathyroid [*para-THIGH-royd*] hormone is necessary for human survival because it controls the blood concentration of what?

ANSWER: CALCIUM (ACCEPT: Ca²⁺)