

## HIGH SCHOOL - ROUND 14A

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### TOSS-UP

1) Earth and Space – *Short Answer* During a solar eclipse, an observer's view of the Sun is completely blocked by the moon. The observer is therefore standing in what region of the Moon's shadow?

ANSWER: UMBRA

### BONUS

1) Earth and Space – *Multiple Choice* Which of the following statements best reflects our current understanding of the past and present of Mars' atmosphere?

- W) It has always been about as thick Earth's atmosphere today
- X) It has always been much thinner than Earth's atmosphere today
- Y) It was thick shortly after formation, but has since thinned due to solar wind
- Z) It was thin shortly after formation, but has since thickened due to volcanic outgassing

ANSWER: Y) IT WAS THICK SHORTLY AFTER FORMATION, BUT HAS SINCE THINNED DUE TO SOLAR WIND

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### TOSS-UP

2) Chemistry – *Short Answer* Identify all of the following three terms that can describe the behavior of water: 1) Nucleophile [*NU-klee-oh-file*]; 2) Lewis base; 3) Bronsted [*BRON-sted*] acid.

ANSWER: ALL

### BONUS

2) Chemistry – *Short Answer* Identify all of the following three statements that are true of crystal field theory: 1) *d* orbitals in a coordinated metal can be higher in energy than in the isolated metal ion; 2) All *d* orbitals are elevated in energy equally when a metal is coordinated; 3) In a coordinated metal ion, the *d* orbitals are degenerate.

ANSWER: 1

**TOSS-UP**

3) Energy – *Multiple Choice* DOE scientists working on the Dark Energy Survey at Fermilab serendipitously discovered a potential dwarf planet orbiting the Sun at 92 AU. Which of the following is closest, in Earth-years, to the orbital period of this object?

- W) 110
- X) 1,100
- Y) 11,000
- Z) 110,000

ANSWER: X) 1,100

**BONUS**

3) Energy – *Short Answer* Researchers supported by Ames Lab have recently provided spectroscopic [*spek-troh-SCAW-pik*] evidence for a type of material in which the electron and hole bands are connected at Weyl [*wile*] points, which are in turn connected by Fermi [*FUR-mee*] arcs. These materials are a specific type of what general group of materials in electronic band theory?

ANSWER: SEMIMETAL

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**TOSS-UP**

4) Physics – *Multiple Choice* Which of the following thermodynamic quantities is a path function?

- W) Energy
- X) Enthalpy [*EN-thul-pee*]
- Y) Entropy [*EN-troh-pee*]
- Z) Heat

ANSWER: Z) HEAT

**BONUS**

4) Physics – *Short Answer* A solid uniform cylindrical rod has moment of inertia  $I$  when rotating about its center like a propeller. In terms of  $I$ , what is the moment of inertia of a second rod of the same density but twice the length, when rotated about its symmetry axis?

ANSWER:  $8 I$

**TOSS-UP**

5) Math – *Multiple Choice* Let  $f(x)$  be a continuous and differentiable function on the closed interval  $[2,6]$ . Which of the following could be the  $x$ -value guaranteed by the mean value theorem for this situation?

- W) 0
- X) 3
- Y) 6
- Z) 9

ANSWER: X) 3

**BONUS**

5) Math – *Short Answer* Solve the following equation for  $x$ :  $4x + 2$  equals the absolute value of open parenthesis  $3x - 5$  close parenthesis.

ANSWER:  $3/7$  (DO NOT ACCEPT:  $-7$ )

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**TOSS-UP**

6) Biology – *Short Answer* Identify all of the following three classes that contain organisms that produce amniotic eggs: 1) Reptilia; 2) Aves [*AY-veez*]; 3) Mammalia.

ANSWER: ALL

**BONUS**

6) Biology – *Multiple Choice* Which of the following codons could NOT result in a nonsense mutation following a single-nucleotide substitution?

- W) GGA
- X) UCG
- Y) CAA
- Z) AGG

ANSWER: Z) AGG

**TOSS-UP**

7) Earth and Space – *Multiple Choice* Which of the following is closest to the average density, in grams per cubic centimeter, of Earth’s core?

- W) 5.5
- X) 7.1
- Y) 8.9
- Z) 12.8

ANSWER: Z) 12.8

**BONUS**

7) Earth and Space – *Multiple Choice* Which of the following metamorphic index minerals is typically FOUND in the metamorphic facies [*FAY-sheez*] granulite?

- W) Chlorite
- X) Kyanite [*KYE-an-ite*]
- Y) Andalusite [*ann-dah-LOO-site*]
- Z) Sillimanite [*SILLih-mah-nite*]

ANSWER: Z) SILLIMANITE

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**TOSS-UP**

8) Physics – *Short Answer* An engineer designs a step-down transformer to convert 240 volts-RMS down to 20 volts-RMS. If the primary winding has 600 turns, how many turns are required on the secondary winding?

ANSWER: 50

**BONUS**

8) Physics – *Short Answer* In volts to the nearest tenth, what is the change in potential from a distance of 3 meters to a distance of 6 meters of a 1-nanocoulomb [*nano KOO-lawm*] point charge?

ANSWER: 1.5

**TOSS-UP**

9) Biology – *Short Answer* What gene-editing method relies on synthetic guide RNAs to direct Cas nucleases [*NEW-klee-aces*] to target sites for gene editing?

ANSWER: CRISPR (ACCEPT: CRISPR/CAS, CRISPR/CAS9)

**BONUS**

9) Biology – *Multiple Choice* In a typical mouse mammalian research model, which type of epithelial [*eh-pih-THEEL-ee-ul*] cell would be most prevalent lining kidney tubules?

- W) Simple cuboidal [*kyoo-BOY-dul*]
- X) Simple columnar
- Y) Simple squamous [*SKWAY-mus*]
- Z) Stratified columnar

ANSWER: W) SIMPLE CUBOIDAL

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**TOSS-UP**

10) Math – *Short Answer* What is the largest prime factor of 165?

ANSWER: 11

**BONUS**

10) Math – *Short Answer* What is the standard deviation of the following list of 4 numbers: 7, 7, 9, 17?

ANSWER:  $\sqrt{17}$

### TOSS-UP

11) Energy – *Multiple Choice* Scientists at Oak Ridge National Lab are simulating the breakdown of lignocellulosic [*ligno-sellyoo-LOH-sik*] biomass in the presence of tetrahydrofuran [*tetra-high-droh-FYOOR-an*], or THF. What purpose does THF serve in this reaction?

- W) Catalyst
- X) Solvent
- Y) Reactant
- Z) Chaotropic [*kay-ah-TROH-pik*] agent

ANSWER: X) SOLVENT

### BONUS

11) Energy – *Short Answer* There is significant interest in thorium as a next-generation fuel for nuclear fission [*FIH-zhun*] reactors. Identify all of the following three statements that are true regarding thorium:

- 1) Thorium can be found in nature as one nonfissile isotope;
- 2) Thorium-232 can undergo neutron capture;
- 3) Thorium-232 is radioactive with a half-life of 21 minutes.

ANSWER: 1 AND 2

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### TOSS-UP

12) Chemistry – *Multiple Choice* A student is interested in the optical properties of chiral [*KYE-ruhl*] molecules, so she successively performs a chlorination, bromination [*broh-min-AY-shun*], and an iodination [*eye-oh-dah-NAY-shun*] of methane. However, she is disappointed to find out that the resulting product demonstrates no optical rotation of polarized light. Which of the following best explains this?

- W) She prepared a racemic [*ray-SEEM-ik*] mixture
- X) Only certain chiral [*KYE-ruhl*] molecules demonstrate optical rotation
- Y) Geometric isomers demonstrate optical rotation, not stereoisomers [*stereo-EYE-soh-murs*]
- Z) Only larger, more complex chiral molecules demonstrate optical rotation

ANSWER: W) SHE PREPARED A RACEMIC MIXTURE

### BONUS

12) Chemistry – *Multiple Choice* Consider the reaction of 1-bromopentane with sodium hydroxide. Which of the following pairs of characteristics apply to this reaction?

- W) S<sub>N</sub>1 at low temperatures and E1 at high temperatures
- X) E1 at low temperatures and S<sub>N</sub>1 at high temperatures
- Y) S<sub>N</sub>2 at low temperatures and E2 at high temperatures
- Z) E2 at low temperatures and S<sub>N</sub>2 at high temperatures

ANSWER: Y) S<sub>N</sub>2 AT LOW TEMPERATURES AND E2 AT HIGH TEMPERATURES

**TOSS-UP**

13) Biology – *Multiple Choice* In the lac [*lack*] operon, allolactose can be classified as what?

- W) Repressor
- X) Inducer
- Y) Promoter
- Z) Transcription factor

ANSWER: X) INDUCER

**BONUS**

13) Biology – *Multiple Choice* In a typical neuron, voltage-gated potassium channels are gated so that they open at what potential, in millivolts?

- W) -100
- X) -70
- Y) -30
- Z) +40

ANSWER: Z) +40

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**TOSS-UP**

14) Math – *Short Answer* Point *P* is one of the vertices of a 42-sided convex polygon. How many diagonals of the polygon have point *P* as an endpoint?

ANSWER: 39

**BONUS**

14) Math – *Short Answer* Give the parametric equations in terms of *t* for the line that is parallel to the vector  $-5\mathbf{i} - 6\mathbf{j} + 2\mathbf{k}$  and that passes through the point (4, -2, 8).

ANSWER:  $x = -5t + 4$ ;  $y = -6t - 2$ ;  $z = 2t + 8$

**TOSS-UP**

15) Energy – *Short Answer* Ames Lab researchers have been studying the atomic-scale geometry of platinum ions when they are incorporated into large, porous complexes consisting of metal cations [*CAT-eye-onz*] and organic ligands [*LIH-gundz*]. What is the name for this group of complexes?

ANSWER: METAL-ORGANIC FRAMEWORKS (ACCEPT: MOFs)

**BONUS**

15) Energy – *Short Answer* Researchers at Oak Ridge National Lab are studying a bacterial species, present in the GI tract of more than 50% of the world's population, that is known to cause ulcers and stomach cancer. What is the full genus [*JEE-nus*]-species name of this bacterium?

ANSWER: *Helicobacter pylori* (ACCEPT: *Campylobacter pylori*)

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**TOSS-UP**

16) Physics – *Multiple Choice* The Fermi [*FUR-mee*] energy of semiconductors lies in which of the following regions?

- W) Valence [*VAY-lence*] band
- X) Band gap
- Y) Conduction band
- Z) Ground state

ANSWER: X) BAND GAP

**BONUS**

16) Physics – *Short Answer* Alison measures the net charge inside a cell to be  $-9.0$  picocoulombs [*PEE-koh KOO-lawms*]. Assuming this charge is perfectly enclosed by the cell membrane, what is the magnitude of the flux, to two significant figures and in newton-meters squared per coulomb, through the cell membrane?

ANSWER: 1.0



### TOSS-UP

17) Earth and Space – *Short Answer* What is the name given to the end moraine [*mohr-AYN*] that denotes the farthest advance of glacial ice?

ANSWER: TERMINAL MORaine

### BONUS

17) Earth and Space – *Short Answer* Identify all of the following three eras that belong to the Phanerozoic [*fah-NAIR-oh-zoh-ik*] eon: 1) Paleozoic [*PAY-leo-ZO-ik*]; 2) Mesozoic [*MEH-zoh-ZOH-ik*]; 3) Cenozoic [*SEN-oh-ZOH-ik*].

ANSWER: ALL

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### TOSS-UP

18) Chemistry – *Multiple Choice* Which of the following atoms has an atomic radius closest to the atomic radius of sodium?

- W) Beryllium [*beh-RILL-ee-um*]
- X) Magnesium
- Y) Calcium
- Z) Strontium [*STRAWNCH-ee-um*]

ANSWER: Y) CALCIUM

### BONUS

18) Chemistry – *Short Answer* Arrange the following three classes of organic compounds in increasing order of electrophilicity: 1) Ketone [*KEE-tone*]; 2) Ester; 3) Amide [*AM-ide*].

ANSWER: 3, 2, 1

**TOSS-UP**

19) Math – *Short Answer* What is the dot product of  $4i - 7j$  and  $5i + 2j$ ?

ANSWER: 6

**BONUS**

19) Math – *Short Answer* A restaurant has a special that allows you to pick any 2 of 11 possible items, and allows 2 of the same item. How many different orders are possible?

ANSWER: 66



**TOSS-UP**

20) Earth and Space – *Short Answer* On the planet Jupiter, what term describes the cooler, dark bands of latitude that correspond to atmospheric downwelling?

ANSWER: BELTS

**BONUS**

20) Earth and Space – *Short Answer* Identify all of the following three statements that are true of cosmic molecular [*moh-LEK-yoo-lur*] clouds: 1) Hydrogen in molecular clouds is typically present as  $H_2$ ; 2) They contain trace amounts of small organic compounds such as formaldehyde; 3) Constituents of molecular clouds are typically present as ions.

ANSWER: 1 AND 2

### TOSS-UP

21) Physics – *Short Answer* In order to solve a physics problem, a student calculates the surface integral of the normal component of an electric field over a particular surface area. What physical quantity is the student determining?

ANSWER: ELECTRIC FLUX

### BONUS

21) Physics – *Short Answer* What is the resonant frequency, in radians per second, of a parallel LC circuit with an inductance of 2 millihenries and a capacitance of 80 microfarads [*micro-FAIR-ad*]?

ANSWER: 2,500

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### TOSS-UP

22) Chemistry – *Short Answer* P orbitals can form what two types of bonds?

ANSWER: SIGMA AND PI

### BONUS

22) Chemistry – *Short Answer* Identify all of the following three molecules that, according to molecular orbital theory, have non-zero bond orders: 1) H-two [*H-2*]; 2) He-two [*H-E-2*]; 3) He-two plus [*H-E-2-plus*].

ANSWER: 1 AND 3

### TOSS-UP

23) Biology – *Short Answer* In fungal [**FUN-gul**] reproduction, what stage is characterized by the haploid [**HAP-loid**] nuclei [**NEW-klee-eye**] of different parents fusing into a single diploid [**DIH-ployd**] nucleus?

ANSWER: KARYOGAMY

### BONUS

23) Biology – *Short Answer* Identify all of the following four phyla [**FYE-lah**] that possess a segmented body plan: 1) Arthropoda ; 2) Mollusca [**mull-US-kah**]; 3) Nematoda; 4) Chordata [**kor-DAH-tah**].

ANSWER: 1 AND 4