LOST ROUND 9

TOSS-UP

1) CHEMISTRY – *Short Answer* The observed kinetic isotope effect of a reaction is 80, which is much higher than the semi-classical maximum of 10. What effect observed at low temperatures causes the greatly increased kinetic isotope effect by allowing the lighter hydrogen to pass through its potential barrier much more rapidly?

ANSWER: QUANTUM TUNNELING

BONUS

1) CHEMISTRY – *Short Answer* Order the following three carboxylic acid derivatives in increasing carbonyl stretching frequency in the infrared spectrum: 1) Ester; 2) Carboxylate; 3) Acid chloride.

ANSWER: 2, 1, 3

TOSS-UP

2) PHYSICS – *Multiple Choice* A stationary electron is released into a region of space where electric and magnetic fields are perpendicular. Which of the following best describes the shape of its trajectory?

W) Straight line
X) Circle
Y) Helix
Z) Cycloid

ANSWER: Z) CYCLOID

BONUS

2) PHYSICS – *Short Answer* A spherical droplet of water combines with another identical droplet of water with equal mass and volume to create a new spherical droplet. By what factor does the terminal velocity of the new droplet increase from the original terminal velocity of the single droplet of water?

ANSWER: $2^{1/6}$

TOSS-UP

3) BIOLOGY – *Multiple Choice* Which of the following agents directly cause vasoconstriction?

W) Thromboxane
X) Angiotensin I
Y) Kallikrein
Z) Atrial natriuretic peptide

ANSWER: W) THROMBOXANE

BONUS

3) BIOLOGY – *Short Answer* Identify all of the following three actions that would cause flaccid paralysis: 1) Inhibition of acetylcholinesterase; 2) Administration of curare; 3) Administration of botulinum toxin.

ANSWER: 2 AND 3

TOSS-UP

4) ENERGY – *Multiple Choice* Scientists at Argonne National Laboratory synthesized many MXene materials to study variations in surface superconductivity. One of the MXenes they synthesized is a titanium selenide MXene, which has a chemical formula of Ti_3C_2Se and methanide carbons. Which of the following describes the oxidation state of the titanium atoms in the MXene they synthesized?

W) All three titanium atoms in the 2+ oxidation state
X) Two titanium atoms in the 2+ oxidation state, one titanium atom in the 4+ oxidation state
Y) One titanium atom in the 2+ oxidation state, two titanium atoms in the 4+ oxidation state
Z) All three titanium atoms in the 4+ oxidation state

ANSWER: Y) ONE TITANIUM ATOM IN THE 2+ OXIDATION STATE, TWO TITANIUM ATOMS IN THE 4+ OXIDATION STATE

BONUS

4) ENERGY – *Short Answer* Researchers at Sandia National Lab discovered a mechanism to make iron in clays reactive under anaerobic conditions by scattering X-rays to determine the electron density of the clays. The scattering of X-rays inside a crystal by valence electrons can be modeled as what type of elastic scattering?

ANSWER: THOMSON SCATTERING

TOSS-UP

5) EARTH AND SPACE – *Short Answer* Novas occur due to the buildup of hydrogen on what astronomical bodies?

ANSWER: WHITE DWARFS

BONUS

5) EARTH AND SPACE – *Short Answer* What type of galaxy contains many O type stars and forms from the collision of a smaller galaxy perpendicular to the disk of a larger galaxy?

ANSWER: RING GALAXY

TOSS-UP

6) MATH – *Short Answer* Solve the equation $\log_2(\log_4 x) = \log_4(\log_2 x)$ for x.

ANSWER: 16

BONUS

6) MATH – *Short Answer* Let S be the set of the first 10 positive integers. How many subsets of S have the property that the number of elements in the subset is itself a member of the subset?

ANSWER: 512

TOSS-UP

7) CHEMISTRY – *Multiple Choice* Which of the following is NOT true about electrophilic aromatic substitution?

W) The intermediate is a positively charged complex
X) Friedel-Crafts acylation does not usually result in polysubstitution
Y) Halogen substituents act as meta directors
Z) The nitration of benzene utilizes a nitronium cation as an electrophile

ANSWER: Y) HALOGEN SUBSTITUENTS ACT AS META DIRECTORS

BONUS

7) CHEMISTRY – *Multiple Choice* Which of the following describes the thermal and photochemical electrocyclic rearrangements of a symmetric diene, respectively?

W) Conrotatory and conrotatory
X) Conrotatory and disrotatory
Y) Disrotatory and conrotatory
Z) Disrotatory and disrotatory

ANSWER: X) CONROTATORY AND DISROTATORY

TOSS-UP

8) PHYSICS – *Multiple Choice* Which of the following best describes how positrons are found on Feynman diagrams?

W) They are represented as always emanating from photons
X) They are represented as fermions moving backwards in time
Y) They are represented as gauge bosons moving forwards in time
Z) They are represented as scalar bosons moving backwards in time

ANSWER: X) THEY ARE REPRESENTED AS FERMIONS MOVING BACKWARDS IN TIME

BONUS

8) PHYSICS – *Multiple Choice* Which of the following is closest to the total energy of a 2 kg object traveling at 3/5 the speed of light?

W) $1.6 * 10^{16}$ joules
X) $2.3 * 10^{17}$ joules
Y) $6.7 * 10^{17}$ joules
Z) $1.2 * 10^{18}$ joules

ANSWER: X) $2.3 * 10^{17}$ JOULES

TOSS-UP

9) BIOLOGY – *Multiple Choice* Which of the following dyes is most often used to stain proteins in SDS-PAGE?

W) Hoechst ***[Her-skt]***
X) Coomassie ***[Ku-mas-si]*** blue
Y) DAPI
Z) Ethidium bromide

ANSWER: X) COOMASSIE BLUE

BONUS

9) BIOLOGY – *Short Answer* By name or number, identify all the following that are an example of permissiveness: 1) Thyroxine increases the effect of epinephrine on beta-adrenergic receptors; 2) Neurotransmitters released by one neuron creates an EPSP in another neuron, increasing the amount of neurotransmitter transmitted to a third neuron; 3) Estradiol upregulates the expression of oxytocin receptors in the uterus.

ANSWER: 1 AND 3

TOSS-UP

10) ENERGY – *Short Answer* Scientists at Lawrence Berkeley National Laboratory detected a theorized particle process known as neutrinoless double-beta decay using a crystal form of molybdenum-100. The scientists were researching this process in order to help determine if neutrinos belong to what class of fermions that are equivalent to their own antiparticle?

ANSWER: MAJORANA FERMIONS

BONUS

10) ENERGY – *Short Answer* Researchers at the Advanced Photon Source used data from macromolecular X-ray crystallography to determine the structure of the Ebola glycoprotein. During the maturation of a viral glycoprotein in the endoplasmic reticulum, N-glycosylation occurs to link the carbohydrate from the anomeric carbon to the amide nitrogen of what amino acid?

ANSWER: ASPARAGINE

TOSS UP

11) EARTH AND SPACE - *Short Answer* Give, by name or number, all of the following 3 statements which are true concerning alfisols: 1) They are found in association with coniferous forests; 2) They are relatively immature; 3) They contain elevated levels of aluminum and iron.

ANSWER: 3 ONLY

BONUS

11) EARTH AND SPACE – *Short Answer* By name or number, identify all the following three statements that are true if the Sun increased its mass to 1.5 solar masses: 1) It would develop a convective core; 2) It would begin the CNO cycle; 3) It would eventually fuse carbon.

ANSWER: 1 AND 2

TOSS-UP

12) MATH – *Short Answer* Determine the smallest positive integer value of n such that $n^2 + 1$ is divisible by $n + 2$.

ANSWER: 3

BONUS

12) MATH – *Short Answer* An isosceles triangle has lateral sides of length 6 and a vertex angle that measures 120º. When the triangle is rotated around one of the lateral sides in 3-D space, a solid figure is formed. What is the volume of this figure?

ANSWER: 54π

TOSS-UP

13) CHEMISTRY – *Multiple Choice* Which of the following sodium salts can be reacted with carbonyl compounds to reversibly form stable crystalline intermediates that can be safely stored and further reacted with greater yields?

W) Sodium nitrite
X) Sodium cyanide
Y) Sodium cyanate
Z) Sodium bisulfite

ANSWER: Z) SODIUM BISULFITE

BONUS

13) CHEMISTRY – *Short Answer* Although the complex ion CuF_6^{4-} ***[Cu-F-sub-6-4-minus]*** has an octahedral geometry according to crystal field theory, it is actually slightly elongated along the z axis due to Jahn-Teller distortions. Order the following three d orbitals in increasing energy in the actual structure of CuF_6^{4-}: 1) d_{z^2} ***[d-sub-z-squared]***; 2) d_{xy} ***[d-sub-xy]***; 3) d_{xz} ***[d-sub-xz]***.

ANSWER: 3, 2, 1

TOSS-UP

14) PHYSICS – *Multiple Choice* A classical and quantum harmonic oscillator each oscillate between $x = L$ and $x = -L$. Which of the following describes the probability distributions of the classical and quantum harmonic oscillators, respectively, at $x = 0$ in the first harmonic?

W) At a minimum, at a minimum
X) At a minimum, at a maximum
Y) At a maximum, at a minimum
Z) At a maximum, at a maximum

ANSWER: X) AT A MINIMUM, AT A MAXIMUM

BONUS

14) PHYSICS – *Short Answer* A particle with charge 1 coulomb is placed at the origin, such that a particle with alternating sign of charge with magnitude 1 coulomb is placed along each unit on the positive x axis. If this operation is carried out infinitely many times, what is the magnitude of the force experienced by the particle at the origin in terms of coulomb's constant k?

ANSWER: $\frac{k\pi^2}{12}$

TOSS-UP

15) BIOLOGY – *Multiple Choice* Which of the following concentrations of auxin would cause stem and root elongation respectively?

W) 10^{-2} M, 10^{-2} M
X) 10^{-12} M, 10^{-12} M

Y) 10^{-5} M, 10^{-11} M
Z) 10^{-11} M, 10^{-5} M

ANSWER: Y) 10^{-5} M, 10^{-11} M

BONUS

15) BIOLOGY – *Short Answer* In contrast to the opsins and rhodopsin, what other photopigment is used by the suprachiasmatic nucleus to coordinate the circadian rhythm?

ANSWER: MELANOPSIN

TOSS-UP

16) ENERGY – *Short Answer* Scientists at Ames National Laboratory have discovered a lanthanum based catalyst for carbon oxygen sigma bond cleavage. Identify all of the following three reactions that this catalyst could be used for: 1) Ozonolysis; 2) Epoxide ring opening; 3) Glycol cleavage.

ANSWER: 1 AND 2

BONUS

16) ENERGY – *Short Answer* Scientists at Lawrence Berkeley National Laboratory grew an ultra-thin layer of a doped hafnium oxide onto silicon. Using X-ray analysis techniques, the scientists discovered that the ultra-thin material both achieved spontaneous electric polarization and reversed the direction of polarization in the presence of an external electric field. What term describes the ultra-thin material?

ANSWER: FERROELECTRIC

TOSS-UP

17) EARTH AND SPACE – *Multiple Choice* Which of the following is NOT a characteristic of chondrites?

W) Glassy chondrules
X) Calcium-aluminum rich inclusions
Y) Presence of Volatiles
Z) Widmanstätten ***[weed-man-stat-ten]*** patterns

ANSWER: Z) WIDMANSTÄTTEN PATTERNS

BONUS

17) EARTH AND SPACE - *Short Answer* Give, by name or number, all of the following three factors which disrupt mesocyclone formation and maturation: 1) Low vertical shear; 2) Presence of neddy eddies; 3) High pressure aloft.

ANSWER: 1 ONLY

TOSS-UP

18) MATH – *Short Answer* Arthur has 5 blue socks, 3 red socks, and 2 green socks. After drawing 3 socks at random from his drawer, what is the probability that he has drawn a pair of socks of the same color?

ANSWER: ¾

BONUS

18) MATH – *Short Answer* Evaluate the line integral of $x^2\ ds$ along the line segment from (–1, 0) to (1, 2).

ANSWER: $2\sqrt{2}/3$

TOSS-UP

19) CHEMISTRY – *Short Answer* Identify all of the following three reactions that will produce a lactone: 1) Dieckmann ***[D-ee-k-man]*** cyclization of a diester; 2) Baeyer-Villiger oxidation of a cyclic ketone; 3) Beckmann rearrangement of an oxime.

ANSWER: 2 ONLY

BONUS

19) CHEMISTRY – *Multiple Choice* What is the HOMO and LUMO, respectively, for the reaction between formaldehyde and potassium cyanide to produce a cyanohydrin?

W) Sigma orbital of cyanide and sigma star orbital of formaldehyde
X) Pi orbital of cyanide and sigma star orbital of formaldehyde

Y) Pi orbital of cyanide and pi star orbital of formaldehyde
Z) Nonbonding orbital of cyanide and pi star orbital of formaldehyde

ANSWER: Z) NONBONDING ORBITAL OF CYANIDE AND PI STAR ORBITAL OF FORMALDEHYDE

TOSS-UP

20) PHYSICS – *Multiple Choice* Under which of the following conditions is the electric field guaranteed to be conservative?

W) Net charge is zero
X) No charge movement
Y) The curl of the electric field is constant
Z) There are no changing magnetic fields

ANSWER: Z) THERE ARE NO CHANGING MAGNETIC FIELDS

BONUS

20) PHYSICS – *Short Answer* What is the hypothetical spin of a tensor boson, and what hypothetical tensor boson derives from the stress-energy tensor?

ANSWER: 2 AND GRAVITON

TOSS-UP

21) BIOLOGY – *Short Answer* In some grasses, increases in population size may lead to an increase in individual fitness, due to shielding of the wind. This is an example of what effect?

ANSWER: ALLEE EFFECT

BONUS

21) BIOLOGY – *Multiple Choice* Which of the following mechanisms best describes how retinoblastoma protein is responsible for the inhibition of the cell cycle?

W) It inhibits the action of E2F
X) It initiates the destruction of MPF
Y) It destabilizes tubulin polymerization
Z) It recruits the action of p53

ANSWER: W) IT INHIBITS THE ACTION OF E2F

TOSS-UP

22) ENERGY – *Short Answer* Scientists at Lawrence Berkeley National Laboratory recently imaged saxiphilin in bullfrogs—an inhibitor of the deadly neurotoxin, saxitoxin, secreted by red tides. What phylum is mainly responsible for blooming red tides and the buildup of saxitoxin in commercial fish?

ANSWER: DINOFLAGELLATA

BONUS

22) ENERGY – *Short Answer* Scientists at Ames National Laboratory discovered that skyrmions, a type of quasiparticle, can reproduce similarly to biological cellular division. While quasiparticles are fermionic, what other type of closely related emergent phenomena in condensed matter physics are bosonic?

ANSWER: COLLECTIVE EXCITATIONS

TOSS-UP

23) EARTH AND SPACE – *Multiple Choice* Which of the following is true about Venus' atmosphere?

W) The thermosphere is the hottest layer of the atmosphere
X) Venus's cloud layer is more stable than Earth's
Y) Jet streams in the upper atmosphere flow from west to east
Z) Clouds of sulfuric acid obscure the surface of Venus from optical imaging

ANSWER: X) VENUS'S CLOUD LAYER IS MORE STABLE THAN EARTH'S

BONUS

23) EARTH AND SPACE - *Short Answer* By name or number, identify all of the following three statements that are consequences of Walker circulation cells during the months of June to August: 1) Eastern North Atlantic basin exhibits cooler surface temperatures; 2) Eastern North Pacific basin exhibits cooler surface temperatures; 3) Eastern Indian Ocean basin exhibits cooler surface temperatures.

ANSWER: 1 AND 2

TOSS-UP

24) MATH – *Short Answer* Determine the sum of the squares of the roots of the polynomial $x^{2020} - 20x^{2019} + 50$.

ANSWER: 400

BONUS

24) MATH – *Short Answer* Two digits A and B are chosen such that the base 7 numeral A2B16 is divisible by 8. What is the sum of A and B?

ANSWER: 5

TOSS-UP

25) CHEMISTRY – *Short Answer* Identify all of the following three statements that are true about the Wolff-Kishner reduction: 1) It occurs under basic conditions; 2) It reduces hydrazones to produce alkanes; 3) Nitrogen gas is produced as a byproduct.

ANSWER: ALL

BONUS

25) CHEMISTRY – *Short Answer* Identify all of the following three statements that are true about the unit cell of rutile, which has an empirical formula of TiO_2: 1) It is tetragonal; 2) The titanium atoms adopt a face centered arrangement; 3) The coordination number of each titanium atom is 4.

ANSWER: 1 ONLY