TOSS-UP

1) Chemistry – *Short Answer* [3] Order the following three ions from most negative to most positive standard reduction potential: 1) Aluminum 3+; 2) Gold 3+; 3) Ruthenium 3+.

ANSWER: 1, 3, 2 [CK]

BONUS

1) Chemistry – *Short Answer* [4] Order the following 3 ligands from weakest to strongest according to the spectrochemical series: 1) H_2O; 2) OH^-; 3) CO.

ANSWER: 2, 1, 3 [CT]

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TOSS-UP

3) Math – *Short Answer* [3] An infinite geometric series has first term 1 and common ratio r. If the series sums to 5/3, what is r?

ANSWER: 2/5 [CT]

BONUS

3) Math – *Short Answer* [3] Let n be a positive integer such that $2^n - 1$ is a Mersenne prime. Identify all of the following 3 statements about n that must be true: 1) n is even, 2) n is odd, 3) n is not divisible by 3.

ANSWER: NONE [CT]

TOSS-UP

4) Biology – *Multiple Choice* [2] In the alternation of generations, the sporophyte and gametophyte are best described by which of the following ploidies?

W) Haploid, haploid
X) Haploid, diploid
Y) Diploid, haploid
Z) Diploid, diploid

ANSWER: Y) DIPLOID, HAPLOID [SF]

BONUS

4) Biology – *Short Answer* [2] Identify all of the following 3 organelles that possess grana: 1) Mitochondria; 2) Nucleus; 3) Peroxisome.

ANSWER: NONE [SF]

TOSS-UP

5) Physics – *Multiple Choice* [4] Alice throws her baseball directly upwards at 10 m/s, while Bob throws his baseball at a 45 degree angle from the horizontal at the same speed. What is the ratio of the maximum height reached by Alice's baseball to Bob's baseball?

W) 1
X) Root 2
Y) 2
Z) 2 root 2

ANSWER: Y) 2 [CT]

BONUS

5) Physics – *Short Answer* [4] Particle A is orbiting the Sun in an elliptical path. At perihelion, particle A is 100 million km from the center of the Sun, while at aphelion, it is at 150 million km away. If particle B has the same perihelion but an aphelion 6 times as far as particle A's aphelion, what is the ratio of the orbital periods of particle A to particle B?

ANSWER: 1 TO 8 [CT]

TOSS-UP

6) Energy – *Multiple Choice* [4] Researchers at Oak Ridge National Lab have used data from the Dark Energy Survey to verify photometrically classified brown dwarfs. In which of the following regions of the electromagnetic spectrum are brown dwarfs best observed in?

W) Radio
X) Infrared
Y) Visible
Z) X-ray

ANSWER: X) INFRARED [YL]

BONUS

6) Energy – *Short Answer* [4] Scientists at Lawrence Livermore National Lab have developed a human identification procedure based on mitochondrial DNA. Identify all of the following 3 statements that are true of mitochondrial DNA: 1) It is single stranded; 2) It is circular; 3) It does not contain essential genes for animal cells.

ANSWER: 2 ONLY [SF]

TOSS-UP

7) Biology – *Multiple Choice* [4] Yuchen wants to measure the concentrations of Ca^{2+} in a mammalian cardiocyte. In which of the following organelles would he measure the concentration of Ca^{2+} to be the highest?

W) Cytosol
X) Smooth endoplasmic reticulum
Y) Lysosome
Z) Nucleus

ANSWER: X) SMOOTH ENDOPLASMIC RETICULUM [SF]

BONUS

7) Biology – *Short Answer* [4] Ecdysteroids ***[EK-dy-steroid]*** often act in accordance with the levels of what other hormone to promote either molting or metamorphosis?

ANSWER: JUVENILE HORMONE [SF]

TOSS-UP

8) Physics – *Short Answer* [4] At time $t = 0$, two waves of frequencies 450 Hz and 500 Hz interfere completely constructively. If the waves have identical velocities, what is the smallest positive value of t such that the waves interfere completely destructively?

ANSWER: 0.01 [CT]

BONUS

8) Physics – *Short Answer* [6] A circular coil has radius 10 meters and lies on the xy plane. It starts traveling at a speed of 5 m/s in the positive x direction. At time $t = 0$, the rightmost tip of the circle enters a 5 tesla magnetic field directed in the positive z direction. At time $t = 3$, what is the magnitude of the induced emf?

ANSWER: 250 ROOT 2 [CT]

TOSS-UP

9) Earth and Space – *Multiple Choice* [4] Which of the following best explains why hurricanes generally cannot form within five degrees of the equator?

W) Equatorial waters are often too cool due to upwelling
X) Equatorial atmospheric circulation is dominated by sinking air
Y) There is not enough Coriolis deflection to produce rotation
Z) There is too much vertical wind shear from the equatorial jet stream

ANSWER: Y) THERE IS NOT ENOUGH CORIOLIS DEFLECTION TO PRODUCE ROTATION [YL]

BONUS

9) Earth and Space – *Short Answer* [6] Identify all of the following three statements that are true of stellar fusion: 1) The proton proton chain is much less sensitive to temperature than the CNO cycle; 2) Stars larger than 5 solar masses usually have a convective core and radiative envelope; 3) The first dredge-up in a star's life cycle may cause the CNO cycle to halt.

ANSWER: 1 AND 2 [SF]

TOSS-UP

10) Chemistry – *Short Answer* [2] What electron quantum number specifies the orientation of orbitals in space for a given energy and angular momentum?

ANSWER: MAGNETIC QUANTUM NUMBER (ACCEPT: MAGNETIC ORBITAL QUANTUM NUMBER; MAGNETIC ORBITAL; M SUB L; M) [CK]

BONUS

10) Chemistry – *Short Answer* [5] Identify all of the following 3 statements about the Clemmensen reduction that are true: 1) It can be used to reduce alkenes; 2) It is base catalyzed; 3) An alcohol intermediate is formed.

ANSWER: NONE [CT]

TOSS-UP

11) Math – *Short Answer* [6] Greg flips 2021 coins. How many times as likely is it for him to get exactly 2019 heads than it is for him to get exactly 2020 heads?

ANSWER: 1010 [CT]

BONUS

11) Math – *Short Answer* [7] A triangle ABC has AB = 1 and angle BAC = 90 degrees. Derek starts at point C and wants to travel to side AB, then side BC, then vertex A, all in the shortest distance possible. What is the minimum length that AC has to be in order for Derek's optimal route to pass through vertex B?

ANSWER: ROOT 3 [CT]

TOSS-UP

12) Energy – *Short Answer* [4] Scientists at Argonne National Lab are studying the properties of a high-pressure glass phase made from molecular parahydrogen. In molecular parahydrogen, the two protons have an opposite value for what quantity?

ANSWER: NUCLEAR SPIN (ACCEPT: SPIN) [YL]

BONUS

12) Energy – *Short Answer* [5] Researchers at Fermilab and Los Alamos National Lab have been monitoring the relativistic jets of M87* ***[M-87 star]***, a supermassive black hole that was recently imaged with the Event Horizon Telescope. Identify all of the following three statements that are true regarding the relativistic jet: 1) It is precessing; 2) It lies perpendicular to the plane of the accretion disk; 3) It has very weak radio emission and can only be observed in high energy wavelengths.

ANSWER: 1 AND 2 [YL (i think)]

TOSS-UP

13) Biology – *Short Answer* [6] According to the acid growth hypothesis, increased auxin concentrations activate proton pumps which acidify the cell wall. The acidified cell wall activates which class of enzymes, responsible for cleaving cross linking polysaccharides between cellulose microfibrils?

ANSWER: EXPANSINS [SF]

BONUS

13) Biology – *Short Answer* [4] A lack of adenosine deaminase may be responsible for what disease, which results when the functions of both the T and B cells are disrupted?

ANSWER: SEVERE COMBINED IMMUNODEFICIENCY (ACCEPT: SCID) [SF]

TOSS-UP

14) Physics – *Multiple Choice* [4] A beam of light travels through air and strikes water with a refractive index of 1.3 such that the reflected beam is completely polarized. Which of the following angles, in degrees, is closest to the angle the incoming beam makes with the vertical?

W) 30
X) 40
Y) 50
Z) 60

ANSWER: Y) 50 [CT]

BONUS

14) Physics – *Short Answer* [3] A uniform cylinder with radius 1 meter has one of its bases on a horizontal table with a sufficiently high coefficient of static friction. A student slowly tips the cylinder until its central axis makes a 30 degree angle with the vertical, at which point the cylinder falls over on its own. To the nearest tenth, what is the height of the cylinder?

ANSWER: 3.5 [CT]

TOSS-UP

15) Math – *Short Answer* [3] How many integers from 1 to 200 inclusive are not divisible by neither 2 nor 3?

ANSWER: 67 [CT]

BONUS

15) Math – *Short Answer* [5] Compute the x coordinate of the only local minimum of the function $y = x^3 + 7x^2 + 8x + 2$.

ANSWER: –2/3 [CT]

TOSS-UP

16) Earth and Space – *Multiple Choice* [6] The Tully-Fisher relation is an empirical correlation between what two parameters of a spiral galaxy?

W) Rotational velocity and luminosity
X) Mass and luminosity
Y) Redshift and distance
Z) Eccentricity and rotational velocity

ANSWER: W) ROTATIONAL VELOCITY AND LUMINOSITY [YL]

BONUS

16) Earth and Space – *Short Answer* [7] What structures, named after their radiating shape, form in the bedrock below meteorite impact craters due to intense compressional and tensional forces during impact?

ANSWER: SHATTER CONES [YL]

TOSS-UP

17) Chemistry – *Short Answer* [2] Identify all of the following three atomic orbitals that are capable of overlapping to form sigma bonds: 1) 1s; 2) 2s; 3) 2p.

ANSWER: ALL [CK]

BONUS

17) Chemistry – *Multiple Choice* [7] Disulfide bond formation is essential in biochemical systems. Which of the following sets of conditions is most conducive to disulfide bond formation from thiols?

W) High pH and reducing environment
X) High pH and oxidizing environment
Y) Low pH and reducing environment
Z) Low pH and oxidizing environment

ANSWER: X) HIGH PH AND OXIDIZING ENVIRONMENT [RB]

TOSS-UP

18) Math – *Short Answer* [7] A unit cube is inscribed in a sphere, and the sphere is inscribed in another cube. What is the volume of the second cube?

ANSWER: 3 ROOT 3 [CT]

BONUS

18) Math – *Short Answer* [5] A complex number z is called a primitive nth root of unity if n is the smallest positive integer such that z to the power of n equals 1. How many distinct primitive 2020th roots of unity exist?

ANSWER: 800 [CT]

TOSS-UP

19) Physics – *Multiple Choice* [4] An RC circuit has a resistance of 10 ohms and a capacitance of 4 farads. At time $t = 0$, the capacitor is completely uncharged, and a switch is flipped so that it starts charging. Which of the following is closest to the time needed, in seconds, for the capacitor to reach half its maximum charge?

W) 30
X) 40
Y) 50
Z) 60

ANSWER: W) 30 [CT]

BONUS

19) Physics – *Short Answer* [8] The expectation value of the z component of an electron's spin is ħ/3 ***[read: h bar over 3]***. What is the probability that a spin measurement along the z axis will result in the spin up state?

ANSWER: 5/6 [DK]

TOSS-UP

20) Earth and Space – *Short Answer* [3] What phenomenon distorts the light behind a massive object and can cause the formation of Einstein rings?

ANSWER: GRAVITATIONAL LENSING [YL]

BONUS

20) Earth and Space – *Short Answer* [5] The radiative flux density of star A is ten thousand times that of star B. If the apparent magnitude of star B is 8.2, then what is the apparent magnitude of star A?

ANSWER: –1.8 [YL]

TOSS-UP

21) Biology – *Short Answer* [5] Identify all of the following three actions that would shift a hemoglobin saturation vs oxygen curve to the left: 1) Increase in pH; 2) Increase in CO_2 concentration; 3) Decrease in 2,3 BPG.

ANSWER: 1 AND 3 [SF]

BONUS

21) Biology – *Short Answer* [7] Vitamin C is needed for the maintenance and formation of new collagen because it is crucial to the hydroxylation of what two amino acids?

ANSWER: LYSINE AND PROLINE [SF]

TOSS-UP

22) Energy – *Short Answer* [6] Researchers at the Joint Genome Institute are identifying fungal enzymes that participate in glycosylation. Identify all of the following three properties of drug-like molecules which are significantly affected by glycosylation: 1) Solubility; 2) Longevity in circulatory system; 3) Pharmacokinetics.

ANSWER: ALL [AS]

BONUS

22) Energy – *Multiple Choice* [kinda hard] Scientists at Los Alamos National Lab are developing new models for vertical mixing in Langmuir circulation. Which of the following would not be characteristic of Langmuir circulation?

W) Aggregation of long strips of plankton
X) Adjacent cells of opposite rotational circulation
Y) Zones of convergence separated by zones of divergence
Z) Driven primarily by Ekman spirals

ANSWER: Z) DRIVEN PRIMARILY BY EKMAN SPIRALS [YL]

TOSS-UP

23) Chemistry – *Multiple Choice* [3] Which of the following molecules has a chiral center?

W) 2-methylpentane
X) 2-methylhexane
Y) 3-methylpentane
Z) 3-methylhexane

ANSWER: Z) 3-METHYLHEXANE [CT]

BONUS

23) Chemistry – *Multiple Choice* In thin layer chromatography, some compounds cannot be visualized using UV and must be stained. Which of the following acids would be most appropriate for staining organic compounds?

W) Hydrochloric acid
X) Sulfuric acid
Y) Boric acid
Z) Phosphoric acid

ANSWER: X) SULFURIC ACID [apc]