TOSS-UP

1) CHEMISTRY *Multiple Choice* Which of the following statements regarding chirality is correct?

W) All compounds containing at least one chiral center are chiral
X) An enantiomerically pure solution of a chiral compound with the "R" designation will rotate plane polarized light to the right
Y) SN1 reactions at chiral centers generally yield racemic mixtures
Z) The term "diastereomers" describes the relationship between two non-superimposable mirror images

ANSWER: Y) SN1 reactions at chiral centers generally yield racemic mixtures

BONUS

1) CHEMISTRY *Short Answer* Identify all of the following solids that will dissolve to a significant extent in 1 molar hydrochloric acid:

1) Silver chloride
2) Calcium phosphate
3) Magnesium hydroxide

ANSWER: 2) and 3)

TOSS-UP

2) BIOLOGY *Multiple Choice* Which of the following modes of endocytosis involves the non-specific uptake of liquids into the cell?

W) Clathrin-mediated endocytosis
X) Phagocytosis
Y) Pinocytosis
Z) Potocytosis

ANSWER: Y) Pinocytosis

BONUS

2) BIOLOGY *Short Answer* Arrange the following three steps of the sliding filament model in skeletal muscle contraction from earliest to latest:

1) ATP binds to actin-myosin complex
2) Actin dissociates from myosin
3) Cross bridges form

ANSWER: 3) 1) 2)

TOSS-UP

3) MATH *Short Answer* Solve the following logarithmic equation for x: ln (2x - 1) = ln (x+2) + ln (x-2) **[read as: the natural log of the quantity 2x minus 1 is equal to the natural log of the quantity x plus two plus the natural log of the quantity x minus 2]**

ANSWER: 3

BONUS

3) MATH *Short Answer* Find the sum of the squares of the integers between 11 and 20, inclusive.

ANSWER: 2485

TOSS-UP

4) PHYSICS *Short Answer* John throws a 10 kg ball at an angle of 30 degrees above the horizontal with an initial speed of 20 m/s. Assuming acceleration due to gravity is ten meters per second squared, what is the maximum vertical height reached by the ball in meters?

ANSWER: 5 meters

BONUS

4) PHYSICS *Multiple Choice* Which of the following three statements are always true regarding ideal solenoids?

1) Ideal solenoids have magnetic fields oriented radially from their central axes.
2) Ideal solenoids have magnetic dipole moments oriented in the same direction as their magnetic fields.
3) If a material with positive permeability is inserted into an ideal solenoid, the magnetic field of the solenoid will increase in magnitude.

ANSWER: 2) only

TOSS-UP

5) EARTH AND SPACE *Multiple Choice* Which of the following igneous rocks is the intrusive equivalent of basalt?

W) Gabbro

X) Pumice
Y) Rhyolite
Z) Obsidian

ANSWER: W) Gabbro

BONUS

5) EARTH AND SPACE *Multiple Choice* Which of the following does NOT correctly match a mineral with its primary constituent element?

W) Sphalerite and zinc
X) Cinnabar and mercury
Y) Gypsum and magnesium
Z) Cassiterite and tin

ANSWER: Y) Gypsum and magnesium

TOSS-UP

6) ENERGY *Multiple Choice* Scientists at the Stanford Linear Accelerator Laboratories are studying paramagnetic organometallic compounds using electron paramagnetic resonance spectroscopy, or EPR. EPR relies on what effect in which the energy levels associated with unpaired electrons are split in a magnetic field?

W) Stark Effect
X) Zeeman Effect
Y) Nernst Effect
Z) Hall Effect

ANSWER: X) Zeeman Effect

BONUS

6) ENERGY *Short Answer* Scientists at Lawrence Livermore National Laboratories are studying the biosynthesis of certain neurotransmitters from tyrosine. Identify all of the following four neurotransmitters they may be studying:

1) Epinephrine
2) Glutamate
3) Norepinephrine
4) Dopamine

ANSWER: 1) 3) 4)

TOSS-UP

7) CHEMISTRY *Short Answer* Given that the pKa of acetic acid is 4.8, determine the pH of a 10 liter solution containing 1 mole of acetic acid and 0.1 moles of acetate.

ANSWER: 3.8

BONUS

7) CHEMISTRY *Multiple Choice* In reductive amination, a primary amine is initially reacted with a carbonyl group to form what functional group, which can be reduced to the target amine by sodium cyanoborohydride?

W) Imine
X) Oxime
Y) Nitrile
Z) Enamine

ANSWER: W) Imine

TOSS-UP

8) BIOLOGY *Multiple Choice* In C3 photosynthesis, the mode of photosynthesis used by the majority of plants, in which of the following cell types does the Calvin Cycle occur?

W) Mesophyll
X) Bundle Sheath
Y) Xylem
Z) Phloem

ANSWER: W) Mesophyll

BONUS

8) BIOLOGY *Multiple Choice* Which of the following hormones is NOT considered an androgen?

W) DHEA
X) Androstenedione
Y) Testosterone

Z) Aldosterone

ANSWER: Z) Aldosterone

TOSS-UP

9) MATH *Short Answer* Given that $sin\ (2x) = 0.8$, evaluate $(sin\ x\ +\ cos\ x)^2$ **[read as: open parentheses, sine of x plus cosine of x close parentheses squared]**

ANSWER: 1.8

BONUS

9) MATH *Short Answer* Suppose an unfair coin that lands heads with probability one-third is flipped 4 times. Find the probability that it lands heads at least twice.

ANSWER: 11/27

TOSS-UP

10) PHYSICS *Short Answer* What formulation of classical mechanics relates potential energy and kinetic energy to determine second-order differential equations of motion?

ANSWER: Lagrangian Mechanics

BONUS

10) PHYSICS *Short Answer* A man sits at halfway between the center and circumference of a merry-go-round of radius 1000 kilometers, which is rotating at a constant angular velocity of 0.01 rad/sec. He throws a ball radially outward at a speed of 20 m/s. In the first 2 seconds of the ball's motion, calculate the magnitude of the Coriolis deflection in meters to one significant figure.

ANSWER: 0.8 meters

TOSS-UP

11) EARTH AND SPACE *Multiple Choice* Star X is a blue supergiant with a luminosity 120,000 times that of the sun and a temperature of 20,000 kelvin. In which of the following regions of the HR diagram is star X located?

W) Bottom Left
X) Top Left

Y) Top Right
Z) Bottom Right

ANSWER: X) Top Left

BONUS

11) EARTH AND SPACE *Multiple Choice* A star belonging to which of the following spectral classes would contain strong titanium oxide bands in its emission spectrum?

W) O
X) F
Y) M
Z) K

ANSWER: Y) M

TOSS-UP

12) ENERGY *Multiple Choice* Scientists at Oak Ridge National Laboratories are developing metal organic frameworks, or MOFs, that are capable of reversibly and repeatedly capturing what free radical pollutant largely responsible for catalyzing the destruction of the ozone layer?

W) Trichlorofluoromethane
X) Sulfuric acid
Y) Sulfur dioxide
Z) Nitrogen dioxide

ANSWER: Z) Nitrogen dioxide

BONUS

12) ENERGY *Multiple Choice* Scientists at Oak Ridge National Laboratories are using neutron diffraction on semiconductor materials to study what hydrogen-like quasiparticles, composed of a bound state between an electron and an electron hole?

W) Phonon
X) Exciton
Y) Magnon
Z) Spinon

ANSWER: X) Exciton

TOSS-UP

13) CHEMISTRY *Multiple Choice* London dispersion forces between individual molecules of which of the following molecules are the strongest?

W) Ethane
X) Methane
Y) Butane
Z) Propane

ANSWER: Y) Butane

BONUS

13) CHEMISTRY *Short Answer* When 6 grams of an un-ionized organic solute are dissolved in 500 grams of water, the freezing point is measured to be -0.057 degrees celsius. Given that the freezing point depression constant for water is approximately -1.9 degrees celsius per molal, determine the molar mass of the solute.

ANSWER: 100 grams per mole

TOSS-UP

14) BIOLOGY *Multiple Choice* Which of the following statements is false regarding rhodophyceae, or red algae?

W) Red algae use chlorophyll as a photosynthetic pigment
X) Red algae are flagellated
Y) Red algae incorporate starch as their primary storage polysaccharide
Z) Red algae are most abundant in saltwater

ANSWER: X) Red algae are flagellated

BONUS

14) BIOLOGY *Short Answer* Ribose-5-phosphate is an essential precursor for the synthesis of many naturally occurring amino acids. The oxidative phase of what metabolic pathway converts glucose-6-phosphate into ribose-5-phosphate?

ANSWER: Pentose phosphate pathway

TOSS-UP

15) MATH *Short Answer* What is the maximum amount of chicken nuggets that cannot be purchased if they are sold in packages of 5 and 8?

ANSWER: 27

BONUS

15) MATH *Short Answer* A right triangle has sides of length 100, 132, and n, where n is between 50 and 100, inclusive. What is the circumradius of this triangle?

ANSWER: 66

TOSS-UP

16) Physics *Multiple Choice* Which of the following mathematical structures best quantifies the moment of inertia of a three dimensional body, when given a specified set of principal axes?

W) Scalar
X) Vector
Y) Tensor
Z) Gradient

ANSWER: Y) Tensor

BONUS

16) PHYSICS *Short Answer* Providing your answer in scientific notation to one significant figure in radians per second, calculate the angular frequency of a monochromatic plane wave of wavelength 400 nanometers propagating in a vacuum at the speed of light.

ANSWER: $5x10^{15}$ radians per second

TOSS-UP

17) EARTH AND SPACE Multiple Choice Which of the following describes the point of a planet's orbit that is closest to the sun?

W) Apogee
X) Perigee
Y) Aphelion **[uh-FEE-lee-uhn]**
Z) Perihelion

ANSWER: Z) Perihelion

BONUS

17) EARTH AND SPACE *Multiple Choice* Which of the following is closest to the mass at which the core of a neutron star collapses when the force of gravity exceeds the outward force of pressure?

W) 2 solar masses
X) 3 solar masses
Y) 4 solar masses
Z) 5 solar masses

ANSWER: W) 2 solar masses

TOSS-UP

18) ENERGY *Short Answer* Scientists at the Joint Genome Institute are characterizing the genome of a double-stranded DNA virus. If they find that 28% of all nucleotides in the viral genome are adenine, what percentage of nucleotides in the genome are guanine?

ANSWER: 22%

BONUS

18) ENERGY *Multiple Choice* Scientists at Brookhaven National Labs are studying the potential application of "click chemistry" in synthesizing modified antibodies. They intend to react an azide functionality with an alkyne functionality to form a stable aromatic triazole. This process exemplifies which of the following types of chemical reaction?

W) Cycloaddition
X) Electrophilic aromatic substitution
Y) Hydrolysis
Z) Bimolecular substitution

ANSWER: W) Cycloaddition

TOSS-UP

19) CHEMISTRY *Short Answer* Identify all of the following three compounds that will exhibit a signal between 1500 and 1800 inverse centimeters in their infrared spectra:

1) Carboxylic acid
2) Ketone
3) Aldehyde

ANSWER: All of them

BONUS

19) CHEMISTRY *Multiple Choice* The molecular orbitals in which of the following diatomic molecules are not subject to s-p mixing?

W) Diboron
X) Dicarbon
Y) Dinitrogen
Z) Dioxygen

ANSWER: Z) Dioxygen

TOSS-UP

20) BIOLOGY *Multiple Choice* Which of the following statements is FALSE regarding K-selected species?

W) K-selected species exhibit extensive parental care
X) K-selected species follow a logistic growth model
Y) Most species of bacteria are K-selected
Z) K-selected species exhibit higher life expectancies

BONUS

20) BIOLOGY *Short Answer* Arrange the following three groups of cytoskeletal polymers in order of increasing average diameter:

1) Actin filaments
2) Keratin filaments
3) Microtubules

ANSWER: 1) 2) 3)

TOSS-UP

21) MATH *Multiple Choice* Find the sum of the squares of the roots of the following equation: $x^3+3x-7x-18=0$ **[read as: x cubed plus 3x squared minus 7x minus 18 equals zero.]**

W) -5

X) 17
Y) 23
Z) 45

ANSWER: Y) 23

BONUS

21) MATH *Short Answer* Calculate the following: $\left(\frac{\sqrt{2}}{2} + \frac{i\sqrt{2}}{2}\right)^{2019}$ **[read as: the quantity square root 2 over 2 plus the i times the square root of 2 over 2, all to the 2019th power]**.

ANSWER: $\frac{-\sqrt{2}}{2} + \frac{i\sqrt{2}}{2}$

TOSS-UP

22) EARTH AND SPACE *Multiple Choice* In which of the following components of the interstellar medium would stellar formation most likely occur?

W) Coronal Gas
X) Intercloud Medium
Y) Molecular Clouds
Z) H I Clouds

ANSWER: Y) Molecular Clouds

BONUS

22) EARTH AND SPACE *Multiple Choice* Which of the following waves produces only horizontal motion and is confined to the surface of the crust?

W) S Waves
X) P Waves
Y) Raleigh Waves
Z) Love Waves

ANSWER: Z) Love Waves

TOSS-UP

23) ENERGY *Short Answer* Scientists at Brookhaven National Labs are studying phase transitions in helium at extremely low temperatures. At temperatures below 2.2 kelvin, Helium-4 exemplifies what form of matter characterized by its lack of viscosity?

ANSWER: Superfluid

BONUS

23) ENERGY *Short Answer* Scientists at Pacific Northwest National Laboratories are studying the formation of baryonic matter in the early universe. Identify all of the following three statements which are correct regarding baryons:

1) All baryons are bosons
2) Protons are considered baryons
3) All baryons are composed of up quarks and down quarks

ANSWER: 2) Only