**TOSS-UP**

1) Chemistry – *Short Answer* An organic chemist conducts a series of experiments to determine the identity of an unknown compound. First, mass spectrometry reveals that the compound has a molecular formula of $C_4H_8$. This does not uniquely determine the identity of the compound since multiple compounds have the same molecular formula but a different arrangement of atoms. What is the term for these kinds of compounds?

ANSWER: ISOMERS (ACCEPT: STRUCTURAL ISOMERS; CONSTITUTIONAL ISOMERS)

**BONUS**

1) Chemistry – *Multiple Choice* According to hard-soft acid-base theory, which of the following elements forms the hardest ions?

W) Sodium
X) Phosphorus
Y) Zinc
Z) Iodine

ANSWER: W) SODIUM

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**TOSS-UP**

3) Math – *Short Answer* Identify all of the following 3 functions that are their own inverse: 1) $x$, 2) 1 over $x$, 3) 1 over the quantity $1 - x$.

ANSWER: 1 AND 2

**BONUS**

3) Math – *Short Answer* *Rich* numbers must start in a 4 and have either 13, 16, or 19 digits. *Poor* numbers must start with a 5 and have 16 digits. To the nearest integer, how many times as many *rich* numbers are there compared to *poor* numbers?

ANSWER: 1001

**TOSS-UP**

4) Biology – *Multiple Choice* Which of the following statements regarding CAM photosynthesis is false?

W) CAM photosynthesis does not utilize PEP Carboxylase
X) CAM photosynthesis is characterized by the opening of stomata in the night
Y) CAM photosynthesis is characterized by a decrease in pH of central vacuole during the night
Z) CAM photosynthesis is more water efficient than C4 photosynthesis

ANSWER: W) CAM PHOTOSYNTHESIS DOES NOT UTILIZE PEP CARBOXYLASE

**BONUS**

4) Biology – *Short Answer* In a hybrid zone between two recently diverged species, the hybrid offspring is more fit than either of the parent species. Identify all of the following three phenomena that are likely to occur: 1) Reinforcement of reproductive barriers; 2) Merging of the two species into a new species; 3) Increase in area of the hybrid zone.

ANSWER: 2 AND 3

**TOSS-UP**

5) Physics – *Multiple Choice* Which of Newton's laws does not apply when considering fictitious forces in a non-inertial reference frame?

W) Newton's first law
X) Newton's second law
Y) Newton's third law
Z) All of Newton's laws apply

ANSWER: Y) NEWTON'S THIRD LAW

**BONUS**

5) Physics – *Short Answer* The moon's diameter is 2/7 that of Earth's, and its surface gravity is 1/6 that of Earth's. To the nearest tenth, what is the ratio of the density of the moon to the density of the earth?

ANSWER: 0.6

**TOSS-UP**

6) Energy – *Short Answer* Researchers at Lawrence Berkeley National Lab have been studying the moisture feedback between soil and the atmosphere. What is the term given to the collective process where water vapor is transferred from soil, plants, and other land sources to the atmosphere?

ANSWER: EVAPOTRANSPIRATION (DO NOT ACCEPT: EVAPORATION; TRANSPIRATION)

**BONUS**

6) Energy – *Short Answer* Scientists at National Renewable Energy Lab are studying communities of cyanobacteria and their effect in bigger ecosystems. Identify all of the following three statements regarding the ecological role of cyanobacteria that are true: 1) They form symbiotic relationships with fungi; 2) They are significantly affected by biomagnification; 3) They are classified as primary producers.

ANSWER: 1 AND 3

**TOSS-UP**

7) Biology – *Multiple Choice* A patient was injured on a skiing trip, and he returns with functioning ears but loss of vision perception. What lobe of his cerebrum has likely been damaged?

W) Frontal
X) Parietal
Y) Temporal
Z) Occipital

ANSWER: Z) OCCIPITAL

**BONUS**

7) Biology – *Short Answer* Hemophilia A is an X linked recessive disease that results from a defective allele for a clotting factor. Assuming that the diseased allele is in Hardy-Weinberg equilibrium, if the probability of a given male having hemophilia is 0.3, what is the frequency of the wild type allele?

ANSWER: 0.7

**TOSS-UP**

8) Physics – *Multiple Choice* A baseball player tosses a ball up in the air, and it eventually falls back down to his glove. Which of the following best describes the sign of the power of gravity acting on the ball?

W) Always positive
X) Always negative
Y) Positive, then negative
Z) Negative, then positive

ANSWER: Z) NEGATIVE, THEN POSITIVE

**BONUS**

8) Physics – *Short Answer* A photon with wavelength 300 nm strikes a piece of metal, and the energy of the ejected electron is 3/5 of the energy of the photon. What is the maximum wavelength, in nm, that another photon can have and still be able to eject an electron from the same piece of metal?

ANSWER: 750

**TOSS-UP**

9) Earth and Space – *Short Answer* Identify all of the following three statements regarding globular clusters that are true: 1) They are generally old and their stars are relatively homogenous in metallicity; 2) Almost all globular clusters are located within the galactic disk of spiral galaxies; 3) Globular clusters have been observed in Andromeda but not the Milky Way.

ANSWER: 1 ONLY

**BONUS**

9) Earth and Space – *Multiple Choice* Europa, Titan, and various other solar system bodies have brown-colored regions due to the presence of compounds known as tholins ***[THOLE-ins]***. Which of the following best characterizes the astrochemical reactions that take place on these moons?

W) Hydrous rocks turn brown in the presence of molecular nitrogen
X) UV light catalyzed reactions between organic molecules create a variety of complex organic solids
Y) Abundant hydrogen gas is trapped in clathrate ice cages, which exhibit a characteristic brown color
Z) Cryovolcanism releases nitrogen dioxide gas, which exhibits a characteristic brown color

ANSWER: X) UV LIGHT CATALYZED REACTIONS BETWEEN ORGANIC MOLECULES CREATE A VARIETY OF COMPLEX ORGANIC SOLIDS

**TOSS-UP**

10) Chemistry – *Short Answer* At standard state, sodium metal crystallizes into a body centered cubic lattice. How many nearest neighbors does each sodium atom have under this arrangement?

ANSWER: 8

**BONUS**

10) Chemistry – *Short Answer* One common method for synthesizing alpha-beta unsaturated carbonyl compounds is aldol condensation. Aldol condensations yield an aldehyde with what other specific functional group?

ANSWER: ALCOHOL (ACCEPT: HYDROXYL)

**TOSS-UP**

11) Math – *Short Answer* A random positive divisor of $2^{2020}$ is chosen. What is the probability that it is odd?

ANSWER: 1/2021

**BONUS**

11) Math – *Short Answer* The curve $y = 1/x$ is rotated around the $x$ axis from $x = 1$ to $x = 4$. What is the volume of the solid formed?

ANSWER: $3\pi/4$

**TOSS-UP**

12) Energy – *Short Answer* Researchers at Brookhaven National Laboratory have been using neutral current interactions to study neutrino flavor oscillations and their mechanism of transformation. Neutral current interactions arise from the weak force. Identify all of the following 3 particles that mediate the weak force: 1) $W^+$ boson; 2) $Z^0$ boson; 3) Higgs boson.

ANSWER: 1 AND 2

**BONUS**

12) Energy – *Short Answer* Researchers at Ames Lab are investigating the magnetic properties of manganese bismuth alloys, which may arise due to their high anisotropy. High anisotropy is characteristic of what state of matter, which has both molecular ordering and fluidity and is commonly found in TV displays?

ANSWER: LIQUID CRYSTAL

**TOSS-UP**

13) Biology – *Short Answer* Identify all of the following three modern eukaryotic organelles which are believed to have resulted from primary endosymbiotic events: 1) Lysosome; 2) Endoplasmic Reticulum; 3) Mitochondria.

ANSWER: 3 ONLY

**BONUS**

13) Biology – *Multiple Choice* Which of the following stimuli is LEAST likely to up-regulate glycogenolysis?

W) Dephosphorylation of glycogen phosphorylase
X) Activation of Protein Kinase A
Y) Rise in cellular epinephrine levels
Z) Rise in cellular cortisol levels

ANSWER: W) DEPHOSPHORYLATION OF GLYCOGEN PHOSPHORYLASE

**TOSS-UP**

14) Physics – *Short Answer* Order the following 3 isotopes from least to greatest neutron to proton ratio: 1) oxygen-16; 2) oxygen-18; 3) fluorine-19.

ANSWER: 1, 3, 2

**BONUS**

14) Physics – *Multiple Choice* Which of the following is NOT true regarding series RLC circuits?

W) If the resistance is sufficiently high, the current will decay without oscillations
X) Impedance is minimized at resonance
Y) Voltage and current are most out of phase at resonance
Z) The frequency of damped oscillations is less than the undamped resonant frequency

ANSWER: Y) VOLTAGE AND CURRENT ARE MOST OUT OF PHASE AT RESONANCE

**TOSS-UP**

15) Math – *Short Answer* What is the ratio of the areas of a regular triangle with side length 1 and a regular hexagon with side length 1?

ANSWER: 1:6

**BONUS**

15) Math – *Short Answer* A regular hexagon has side length 1, with two sides parallel to the x axis. The hexagon is dilated by a factor of 2 in the x direction. What is the new area of the hexagon?

ANSWER: 3 ROOT 3

**TOSS-UP**

16) Earth and Space – *Multiple Choice* Vicky, an aspiring igneous petrologist, finds a relatively coarse-grained whitish-pink igneous rock with specks of black biotite. At first, he foolishly classifies the rock as an alkali granite, but upon further inspection, finds a stark absence of quartz within the rock. Which of the following rocks has Vicky most likely found?

W) Norite
X) Syenite ***[SIE-en-ite]***
Y) Dacite ***[DA-site]***
Z) Diabase

ANSWER: X) SYENITE

**BONUS**

16) Earth and Space – *Short Answer* Mars orbits the sun with an average distance of 1.5 AU. To the nearest integer, how many times as far away is Mars from Earth when it is at its furthest point from Earth than during its closest approach to Earth?

ANSWER: 5

**TOSS-UP**

17) Chemistry – *Short Answer* Identify all of the following three statements that are true regarding periodic trends among the alkali metals: 1) Bond strength to chlorine increases monotonically down the group; 2) Ionization energy increases monotonically down the group; 3) All alkali metals exhibit a red flame test.

ANSWER: NONE

**BONUS**

17) Chemistry – *Multiple Choice* Which of the following organic compounds is not a heterocycle?

W) Benzene
X) Pyridine
Y) Tetrahydrofuran
Z) Furan

ANSWER: W) BENZENE

**TOSS-UP**

18) Math – *Short Answer* Compute the last two digits of $5^{2020}$.

ANSWER: 25

**BONUS**

18) Math – *Short Answer* An arithmetico–geometric sequence is defined such that its $n$th term is the product of the $n$th term of an arithmetic sequence and the $n$th term of a geometric sequence. What is the sum of the infinite arithmetico–geometric sequence formed from the arithmetic sequence with first term 1 and common difference 2 and geometric sequence with first term 1 and common ratio 1/2?

ANSWER: 6

**TOSS-UP**

19) Physics – *Multiple Choice* A proton and an electron are both traveling north at a speed of 300 m/s when they enter a 20 tesla magnetic field directed eastward. Assuming the proton and electron do not interact with each other, which of the following best describes the paths of the particles?

W) The paths are circular and the radius of the proton's path is larger
X) The paths are circular and the radius of the proton's path is smaller
Y) The paths are helical and the radius of the proton's path is larger
Z) The paths are helical and the radius of the proton's path is smaller

ANSWER: W) THE PATHS ARE CIRCULAR AND THE RADIUS OF THE PROTON'S PATH IS LARGER

**BONUS**

19) Physics – *Short Answer* A 2 kilogram block lies stationary on a ramp inclined 60° to the horizontal. To two significant figures, what is the minimum coefficient of static friction between the block and the ramp?

ANSWER: 1.7

**TOSS-UP**

20) Earth and Space – *Multiple Choice* Which of the following statements regarding cinder cones is true?

W) They usually have periodic eruptive cycles
X) They erupt non-viscous lava that builds gentle slopes
Y) Their eruptions are usually associated with large amounts of ash
Z) The erupted material is mostly pyroclastic

ANSWER: Z) THE ERUPTED MATERIAL IS MOSTLY PYROCLASTIC

**BONUS**

20) Earth and Space – *Multiple Choice* Which of the following statements best describes the chemical weathering of iron-bearing pyroxenes?

W) Iron (II) is oxidized to iron (III) and silica is released as a dissolved product
X) Iron (III) is reduced to iron (II) and silica is released as a dissolved product
Y) Iron (II) and silica ions are dissolved into water and later precipitated as iron-bearing olivine
Z) Iron (II) and silica ions are dissolved into water and later precipitated as iron-bearing pyroxene

ANSWER: W) IRON (II) IS OXIDIZED TO IRON (III) AND SILICA IS RELEASED AS A DISSOLVED PRODUCT

**TOSS-UP**

21) Biology – *Multiple Choice* Tyler the avid Hawaiian zoologist comes upon an organism at the beach with only two germ layers. Which of the following phyla could it belong to?

W) Porifera
X) Cnidaria
Y) Echinodermata
Z) Placozoa

ANSWER: X) CNIDARIA

**BONUS**

21) Biology – *Short Answer* Order the following three leukocytes from most to least abundant in the blood: 1) Eosinophil; 2) Monocyte; 3) Neutrophil.

ANSWER: 3, 2, 1

**TOSS-UP**

22) Energy – *Short Answer* Researchers at Pacific Northwest National Lab have been studying ways to more efficiently produce photocatalysts based on films made from rutile and anatase. Anatase and rutile principally contain which transition metal?

ANSWER: TITANIUM

**BONUS**

22) Energy – *Multiple Choice* Researchers at the Joint Genome Institute are studying the effects of mechanical stress on the relationship between nitrogen fixing bacteria and plants. Which of the following genera are they most likely studying?

W) Staphylococcus
X) Vibrio
Y) Clostridium
Z) Rhizobium

ANSWER: Z) RHIZOBIUM

## TOSS-UP

23) Chemistry – *Multiple Choice* Chemists often classify amino acids as either hydrophobic or hydrophilic according to the chemical nature of their R-groups. An amino acid possessing which of the following functional groups in its sidechain may be classified as hydrophobic?

W) Hydroxyl
X) Amino
Y) Carboxylic acid
Z) Methyl

ANSWER: Z) METHYL

## BONUS

23) Chemistry – *Short Answer* The Born Haber cycle makes use of Hess's law to compute the lattice energy of an ionic solid as a summation of individual steps. Identify all of the following three processes that are considered in the Born Haber cycle for calcium iodide: 1) First ionization energy of iodine; 2) Heat of sublimation of iodine; 3) Electron affinity of calcium.

ANSWER: 2 ONLY