TOSS-UP

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

BONUS

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. Then, lack of reaction with bromine water reveals that the compound contains no double bonds. How many different compounds could this be?

ANSWER: 2

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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* Visa numbers must start in a 4 and have either 13, 16, or 19 digits. Mastercard numbers start in either 51, 52, 53, 54, or 55, and must have 16 digits. To the nearest integer, how many times as many Visa numbers are there compared to Mastercard numbers?

ANSWER: 2002

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 plants, soil, 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 Hardy-Weinberg equilibrium, if the probability of a given male having hemophilia is 0.18, what is the frequency of the wild type allele?

ANSWER: 0.82

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 that gravity exerts 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* If the Compton wavelength of an electron is 2.4 picometers, what will be the new wavelength of a 72 picometer X-ray that backscatters at 180°, to the nearest picometer?

ANSWER: 77

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* 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

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. Identify all of the following three statements that are correct regarding this reaction: 1) It may be acid catalyzed; 2) It may be base catalyzed; 3) High temperature favors the condensation product over the addition product.

ANSWER: ALL

TOSS-UP

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

ANSWER: 1/4041

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 are mediated by what particle?

ANSWER: Z_0 BOSON (ACCEPT: Z BOSON)

BONUS

12) Energy – *Short Answer* Researchers at Ames Lab are investigating the magnetic properties of manganese bismuth alloys which may arise from its high anisotropy. Which of the following anisotropic phases, similar to isotropic liquids but having long-range positional order and lacking planar layering, do manganese bismuth alloys take?

W) Nematic
X) Smectic
Y) Cholesteric
Z) Discotic

ANSWER: W) NEMATIC

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 – *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

BONUS

14) Physics – *Short Answer* From each of the following 3 isotopes, a random nucleon is selected, and a random quark is selected from that nucleon. Order the following 3 isotopes from least to greatest probability that this quark is an up quark: 1) oxygen-16; 2) oxygen-18; 3) fluorine-19.

ANSWER: 2, 3, 1

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 perimeter of the hexagon?

ANSWER: 4 PLUS 2 ROOT 7

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 two significant figures, how many times as bright does Mars appear during its closest approach to Earth than when it is at its furthest point away from Earth?

ANSWER: 25

TOSS-UP

17) Chemistry – *Short Answer* Identify all of the following three statements that are true regarding periodic trends among the alkali metals: 1) Ionic radius increases monotonically down the group; 2) Ionization energy increases monotonically down the group; 3) Boiling point increases monotonically down the group.

ANSWER: 1 ONLY

BONUS

17) Chemistry – *Multiple Choice* Which of the following organic heterocycles has a hydrogen deficiency index of three?

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

ANSWER: Z) FURAN

TOSS-UP

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

ANSWER: 625

BONUS

18) Math – *Short Answer* An arithmetico–geometric sequence is defined such that its nth term is the product of the nth term of an arithmetic sequence and the nth 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 – *Short Answer* A 2 kilogram block lies stationary on a ramp inclined 60° to the horizontal. To two significant figures, what is the minimum possible coefficient of friction between the block and the ramp?

ANSWER: 1.7

BONUS

19) Physics – *Short Answer* A particle with charge 2 nanocoulombs and mass 1g is traveling at 3 million meters per second eastward when it enters a 20 tesla magnetic field directed northward. To two significant digits and in scientific notation, what is the radius of the particle's new circular path in meters?

ANSWER: $7.5 * 10^{10}$

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* 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

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 certain diazotrophs 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