

1. Magnesium perchlorate is an effective catalyst for reactions of this type involving silyl ketene acetals. DABCO performs an aza-version of this reaction in the first step of an atom-economic coupling of aldehydes and electron-deficient alkenes called the Morita–Bayliss–Hillman reaction. Like the aldol reaction, silyl enol ethers can undergo a variant of this reaction named for (\*) Mukaiyama. This reaction is followed by an aldol condensation in the Robinson ring annulation. Gilman reagents and resonance-stabilised nucleophiles preferentially perform this reaction instead of direct attack of the carbonyl pi-star orbital. For 10 points, name this reaction where carbanions undergo 1,4-conjugate addition to alpha-beta unsaturated carbonyls.

ANSWER: Michael addition or Michael reaction [accept 1,4-conjugate addition before mentioned; prompt on “addition”; accept Mukaiyama–Michael Addition before “aldol”]

2. An “on-shell” method for this process doesn’t work when massless particles can be emitted, because then there is no finite energy gap between one and multiparticle states in the spectral representation. A differential equation that characterizes quantities like mass and the wave function under this transformation is named for Callan and Symanzik. Counterterms are added to the Lagrangian in order to do this, but when in 4D, this process is impossible for operators whose mass dimension is greater than 4. The most common scheme for doing this involves setting the number of dimensions to 4 minus epsilon. The (\*) beta function quantifies how this process changes a coupling constant. A basic, but not Lorentz-invariant, scheme for doing this imposes a finite energy cutoff. This process is necessary because closed loops in Feynman diagrams involve the integral over possible loop momenta, which may not be finite. For 10 points, identify this mathematical procedure for removing divergences from physical theories such as QED.

ANSWER: renormalization group methods [accept regularization]

3. Optimizing the layout of these systems can be achieved with the Solovay–Kitaev algorithm. These systems are characterized by five criteria put forth by David DiVincenzo. Specialized programming languages for these systems include the Haskell-based Quipper and Microsoft’s LIQüiD. A universal model of these systems was proposed in a classic 1985 paper by David (\*) Deutsch. A barrier to error correction in these systems is the no-cloning theorem. An analog of the reversible XOR gate, the CNOT gate, which stands for “controlled not,” is used in these systems because all universal gate designs require it in order to be able to approximate any unitary operation to arbitrary accuracy. Algorithms designed for these systems include Grover’s search algorithm. For 10 points, identify these systems whose basic unit of information is the qubit.

ANSWER: quantum computers

4. Exposed fossil beds from this period can be seen at Falls of the Ohio State Park in Clarksville, Indiana. The *Archaeopteris* was a tree from the end of this period which was the oldest tree known until the discovery of the *Wattieza*, also from this period. This period included the beginning of the Antler orogeny and the collision of Laurasia and Baltica to form the supercontinent Euramerica. The Gogo formation is a Lagerstätten from this period that contains the only discovered specimen of *Materpiscis*, the earliest known vertebrate to undergo live birth. *Psammosteid heterostracans* survived the (\*) Kellwasser event at this period’s Frasnian–Famennian boundary, which caused the extinction of stromatoporoids and other reef-builders, but they perished in the Hangenberg event, which also wiped out the placoderms that had dominated this period’s shallow, warm seas. For 10 points, identify this geologic time period nicknamed the “Age of Fishes” that preceded the Carboniferous and followed the Silurian.

ANSWER: Devonian period

5. John Vaszquez's interpretation of this thinker is the subject of the essay "Evaluating Theories" by Kenneth Waltz. This thinker described the techniques of "monster-barring," "monster-adjustment," and "exception handling" in one work. This thinker described the process of generating theorems as a "sausage machine." A work by this man is framed as a Socratic dialogue where students named after Greek letters try to derive the (\*) Euler characteristic formula for a polyhedron. This thinker developed a concept that consists of a "hard core" surrounded by a "protective belt," which can be approached via positive or negative heuristics in order to reconcile Kuhn's normal science with Popper's falsificationism. For 10 points, name this author of *Proofs and Refutations* and *The Methodology of Scientific Research Programmes*, a Hungarian philosopher of science.

ANSWER: Imre Lakatos [or Imre Avrum Lipschitz; or Imre Molnár]

6. These structures have a  $1J_{\text{Ca-Ha}}$  ("one-J C-A H-A") coupling constant of 146.5 hertz. A phenomenon exhibited by these structures corresponds mathematically to a large, acoustic, and weakly coupled polaron. Wenxiang ("wun-shee-ong") diagrams depict these structures, which propagate energy via Davydov solitons. Connecting loops between these structures are the locations of NPA motifs. These structures show strong minima at (\*) 208 and 222 nanometers in circular dichroism spectroscopy. Lysine acetylation takes place at hydrophobic binding sites created by the interaction of four of these structures in a bromodomain. Heptad repeats form when two of these structures dimerize into a leucine zipper. For 10 points, hydrogen bonds at every fourth amino acid characterize what type of protein secondary structure that is contrasted with a beta sheet?

ANSWER: alpha helix [or alpha helices; prompt on "helix" or "helices"]

7. This film's score is credited as "electronic tonalities" created by Bebe and Louis Barron. A cook in this film requests some alcohol and is asked in response "Would sixty gallons be sufficient?" A tiger that had previously been docile in the presence of this film's only female character attacks her on sight after she has her first kiss. In this film's only battle scene, atomic disintegrator blasts reveal the outline of a creature that had earlier torn Chief Quinn limb from limb. Much of this film takes place at the house of (\*) Dr. Morbius, who has unknowingly re-awakened the "monsters from the id" that long ago destroyed a hyper-advanced alien race called the Krell. In this film, Leslie Nielsen plays a young spaceship commander who leads a mission to Altair IV to re-establish contact with a group of United Planets colonists. For 10 points, name this 1956 film whose poster shows Anne Francis being carried by Robby the Robot.

ANSWER: Forbidden Planet

8. These things are defined in terms of both requirements and impacts by Chase and Leibold, who use Tilman's ZNGI ("zin-gee") formalism to analyze them graphically. Stephen Hubbell's Unified Neutral Theory represents a null hypothesis for the existence of these things by assuming equivalence among individuals. Joseph Connell used *Chthamalus stellatus* and *Balanus balanoides* in a landmark study of the (\*) realized width of these things. Grinnell and Elton developed alternate environmental and biotic conceptions of these things. G. E. Hutchinson defined the "fundamental" type of these things as an  $n$ -dimensional hypervolume, where each axis corresponds to a different resource. The "paradox of the plankton" was posed due to an apparent violation of Gause's law of competitive exclusion concerning the overlap of these things for different species. For 10 points, name this term that refers to the role played by an organism in its habitat.

ANSWER: ecological niches

9. The  $n$ th of these functions evaluated at  $x$  equals the hypergeometric function  ${}_2F_1$  of negative  $n$ , comma,  $n$  plus one, semicolon, 1, semicolon,  $1 - x$  over 2. The square of the  $n$ th of these functions is greater than the product of the  $n$  minus one-th and the  $n$  plus one-th according to Turan's inequality. These functions' orthonormality conditions involve  $2$  over  $2L + 1$  times the Kronecker delta. Problems in spherical coordinates but with azimuthal symmetry are often solved using these functions. Their (\*) "associated" functions appear evaluated at cosine of theta when solving the Schrödinger equation in spherical coordinates. The eigenfunctions angular momentum can be written as a normalization constant times an exponential times one of these functions of cosine theta; those are the spherical harmonics. For 10 points, name this set of orthogonal polynomials that appear in the angular portion of the wavefunction of a hydrogen atom.

ANSWER: Legendre polynomials [prompt on "spherical harmonics"]

Commented [1]: ?

10. CTEQ provides a software framework for using a certain set of "distribution functions" which are most commonly used in analyzing this particle. Minimally supersymmetric standard model theories impose R-parity to ensure this particle's stability. The difference in the first moments of structure functions of this particle and a heavier one are given by the Bjorken sum rule. In some theories beyond the Standard Model such as the Georgi-Glashow model, the decay of this particle is mediated by a very (\*) heavy X boson. Several grand unified theories posit the decay of this particle to a positron and a pion on extremely long timescales. Experiments such as those at the Super-Kamiokande have given the half-life for that decay a lower bound of more than 10 to the 33 years. Isospin was introduced to describe this particle and a heavier partner, and this particle has two up quarks and one down. For 10 points, name this charged nucleon.

ANSWER: proton

11. This model was modified to fit parameters at infinite dilution by Gmehling et al., creating a common version of this model named for Dortmund. One of its parameters often uses a modified Flory-Huggins potential that incorporates rigidity and ring-formation propensities, called the Staverman-Guggenheim potential. For binary systems, this group-contribution method is equal to a related method using a first-order truncation of a lattice. This model, which only works for non-electrolyte, non-polymeric solutions, was published in 1975 by Fredenslund, Jones, and Prausnitz. This activity model of vapor-liquid equilibrium data contains the combinatorial and residual terms, whose natural logarithms are added together. For 15 points, name this (\*) "Universal" model used to semi-empirically determine activity coefficients in a mixture of liquids.

ANSWER: UNIFAC [accept UNIQUAC because the clues overlap]

12. GRAIL is a multi-agent neural network system for accomplishing this task. Lukashin and Borodovsky pioneered using a three-periodic Markov model to accomplish this task. Programs such as MZEF and SORFIND uses hexamer frequency as one of the main variables to do this task. Models to do this task needed to be improved after a landmark discovery by Phillip Sharp and Richard Roberts, which in many cases must now look for (\*) GT/AG motifs. Accomplishing this task may involve looking for nearby Gilbert or Pribnow Boxes. Doing this task requires to consider differences in GC content between transcribed and non-transcribed regions. A basic way to do this task is to find long open reading frames that are near poly-A signals and promoter regions. For 10 points, name this task that tries to find which part of an organism's DNA code for RNA or protein.

ANSWER: gene finding [or gene prediction; accept descriptions like "finding what DNA regions code for genes"]

13. Observations of 103P/Hartley 2 supports one hypothesis to explain this event, but a drawback is that that object would have a relatively short lifetime. One drawback for a hypothesis for this event is that the upper mantle has a significantly higher ratio of osmium-187 to osmium-188 than carbonaceous chondrites. One theory for this event is supported by observations of MWC 480 and the presence of forsterite olivine. The two-fold difference between the ratio of deuterium to regular hydrogen in comets and that on Earth makes the comet impact hypothesis an unlikely cause of this event. Exogenous sources for this event would have then come from (\*) icy planetesimals and planetary embryos. For 10 points, name this event whose outcome eventually covered about 70 percent of the Earth's surface.

ANSWER: the origin of water on Earth

14. The Wegscheider cyclicality conditions find this quantity for small or large networks. This quantity's initial value is the dependent variable of the Greco-Hakala equations, which are specialized forms of the Morrison equation. The maximum value of this quantity corresponds to the peak of a volcano curve, according to the Sabatier principle. This extensive quantity decreases as exergonicity increases in the (\*) inverted region of Marcus theory. This quantity is plotted on the vertical axis of an Eadie-Hofstee diagram. The time dependence of this quantity for an enzyme binding process can be computed by applying nonlinear regression to the Michaelis-Menten equation. This quantity is independent of concentration for a zero-order reaction. For 10 points, name this quantity whose equilibrium value for a time-invariant elementary reaction is the same in the forward and reverse directions.

ANSWER: reaction rate [or reaction velocity; do not accept "rate constant" or "rate coefficient"]

15. Objects used in this practice are classified into "imponderables," "socodes," and "nosodes." Techniques used in this practice include the Korsakovian method and "succussion," the latter of which produced positive results in a 1988 experiment by Jacques Benveniste. George Vithoulkas is a contemporary authority on this practice, whose originator developed the concepts of "miasms" and "provings" in works like *The Organon of the* (\*) *Healing Art* and was named Samuel Hahnemann. Followers of this practice believe in the "silica hypothesis" and make mother tinctures. Critics of this practice attempt "mass suicides" that have never killed any of the participants, while its proponents cite doctrines like "patterned solvents" and "water memory" to explain this practice's supposed efficacy. For 10 points, name this pseudoscience based on the absurdly stupid idea that medicine becomes more potent the more it is diluted.

ANSWER: homeopathy

16. This software represents a fin-shaped layout of 164 items in a 15-element array, though element 10 is 0. A variant of this software edits a JPEG of Interacting Galaxy System NGC 6745 to respond to a blank JPEG. Variants of this software may contain the font Palida Narrow; zlib, sqlite3, and the Lua VM; or an embedded TTF. This software includes drivers signed by a Taiwanese hardware company. Ralph Langner, the non-profit ISIS, and Hungary's CrySyS ("cree-seece") Lab wrote reports on this software, and Boldizsár Bencsáth (\*) named a variant of this software after the file prefix ~DQ. That variant of this software waits for 10 minutes of user inactivity before keylogging. It is only intended to run on certain Siemens 315 or 417 control systems. The Equation Group may have developed this software and variants like Duqu and Flame for Operation Olympic Games using tons of zero-day exploits. For 10 points, what Israeli-American cyber weapon caused centrifuges enriching uranium to spin out of control at Iran's Natanz nuclear facility around 2009?

ANSWER: Stuxnet [anti-prompt on "Duqu," "Flame," or "Gauss," I guess]

17. For exponential families, Firth showed that penalizing the likelihood with the Jeffreys prior decreases this quantity. Cox and Snell developed analytic expressions for this quantity's decline with Fisher information. Consistency of an estimator requires that this quantity converge toward zero as sample size increases. Jensen's inequality may be used to determine how a transformation affects the sign of this quantity. The mean squared error can be decomposed into irreducible error, the (\*) variance of the estimator, and the square of this quantity. For standard deviation, the Bessel correction reduces this quantity, which in linear regression may be introduced by omitted variables. The Gauss–Markov theorem proves that ordinary least squares has the least variance among estimators with a value of zero for this quantity. This quantity faces a trade-off with variance. For 10 points, name this systematic deviation between the expected value of an estimator and the true value of a parameter.

ANSWER: bias

Commented [2]: Pg

18. This character exclaims “Good news – I’m back! *Bad news – I’m back!*,” then takes out a room full of bad guys just moments after recovering from a grievous throat wound. While hiding in a cave outside Argon City, this character trains the mechanic Beck to assume the role of the Renegade. In this character’s first film appearance, he travels with his love interest Yori to an I/O tower. His suit, which features (\*) four dots on his chest, changes color from red to white during a light-ship chase over the Sea of Simulation. This character had earlier been captured by CLU (“clue”), who turned him into the [double-identity-disc-wielding] evil henchman Rinzler. He gains the ability to defeat the MCP by communicating with Alan Bradley, who, like this character, is played by Bruce Boxleitner. For 10 points, identify this badass computer security program who fights for the Users in a namesake Disney franchise.

ANSWER: Tron

19. This quantity decreases when reading from left to right on a halo merger tree, and its correlation with other galactic properties is the subject of halo abundance matching. Reverberation mapping is a method of estimating this quantity. The Kroupa broken exponential and the  $-2.35$  power law are probability distribution functions for the initial value of this quantity in a (\*) population of stars. A certain form of this quantity equals 1.18 times the fourth power of isothermal sound speed, divided by the square root of the product of pressure and the cube of big  $G$ . The ratio of this quantity to magnetic flux governs whether a molecular cloud is subcritical or supercritical. This quantity decreases very rapidly in Wolf–Rayet stars. For 10 points, the Tolman–Oppenheimer–Volkoff and Chandrasekhar limits are upper bounds on what quantity for certain stars?

ANSWER: mass

Commented [3]: Black hole mass accept

20. This scientist is the namesake of a phenomenon that appears as diagonal associations of surface height anomalies on a Hovmöller diagram. The product of vertical scale height and the Brunt–Väisälä frequency is proportional to this scientist’s namesake radius of deformation. In the Rhines effect, two-dimensional turbulence interacts with a phenomenon named for this scientist that arises due to the conservation of potential vorticity. When a (\*) dimensionless quantity named for this scientist is much smaller than unity, the effects of rotation are dominant, enabling the use of the geostrophic approximation. For 10 points, identify this meteorologist who names a type of planetary wave that produces meanders in jet streams and a number that equals the ratio of inertial to Coriolis forces.

ANSWER: Carl-Gustaf Arvid Rossby

21. In axiomatic quantum field theory, this scientist's namesake causality condition constrains the value of the S-matrix. This scientist formulated a statement that is used to construct the analytic continuations of Wightman functions and is called the edge-of-the-wedge theorem. Elementary excitations in Bose–Einstein condensates satisfy this scientist's namesake dispersion relation. Under the mean-field approximation, inhomogeneous superconductors are described by a diagonalized Hamiltonian named for this scientist and (\*) de Gennes. He is the alphabetically first namesake of an equation that is used in variational approaches to calculate the upper bound of Helmholtz free energy. For 10 points, identify this Russian mathematician and physicist who co-names an inequality with Gibbs and is the first namesake of the BBGKY hierarchy.

ANSWER: Nikolai Nikolayevich Bogoliubov

22. In one experimental procedure, these things can be analyzed graphically using the Ponchon–Savarit method. Poppe plots show the generation of these things versus efficiency. The square-root of the number of these things is divided by 4 in both the peak-capacity equation and the resolution equation. In another procedure, the number of these things equals “sixteen times the square of the ratio of peak (\*) retention time to peak width.” These things are represented by right triangles connecting the stripping and rectifying operating lines with the equilibrium curve on a McCabe–Thiele diagram. Multipath, longitudinal diffusion, and mass transfer coefficients appear in the Van Deemter equation for calculating the [height equivalent to one of these things], which is a measure of the efficiency of a chromatographic column. For 10 points, the Fenske equation gives the minimum necessary number of what theoretical constructs that correspond to vaporization/condensation cycles in separation processes like distillation?

ANSWER: theoretical plates [or theoretical stages; or ideal stages; prompt on “plates” or “(equilibrium) stages”]

23. In a dynamical systems approach to simulations of this theory, York extended Lichnerowicz's decomposition on the Hamiltonian and momentum constraints. One formalism used in this theory includes the lapse and the shift function to characterize a foliation. Heuristic conditions imposed to get rid of non-physical possibilities in this theory are called energy conditions. Teukolsky, known for numerical calculations in this theory, showed with a partner that a certain object can form in fine-tuned conditions which violate the hoop conjecture. Identities that involve (\*) permuting some indices, named for Bianchi, are often useful in this physical theory. One quantity central quantity in this theory is described by a rank-two tensor. The equations central to this theory include  $8\pi$  times the stress-energy tensor over  $c$  to the fourth, and include solutions named for Reissner and Nordstrom, Kerr, and Schwarzschild. For 10 points, the Einstein field equations are central to what theory that predicts the curvature of spacetime?

ANSWER: general relativity [or GR; prompt on “(numerical) relativity”; do not accept “special relativity” or “SR”]

24. Purkinje cell “window currents” are sensitive to this toxin. Poisoning with this toxin was divided into four stages by Fukuda and Tani. This bacterial toxin is in the cutis and proboscis of “Himomushi,” or ribbonworms. Granular glands make this alkaloid in rough-skinned newts in Japan and California. It's not conotoxin or saxitoxin, but it was used to isolate the [alpha or pore subunit] of one electric eel ion channel. Robert B. Woodward elucidated this toxin's structure in 1964. This toxin and cadmium ions can bind near the DEKA ring, or selectivity filter, of a voltage-gated ion channel that has nine types. Resistance to this guanidinium toxin slows the crawling of garter snakes. James Cook ate it in New Caledonia in 1774. In *The (\*) Serpent and the Rainbow*, Wade Davis said that this toxin turned Haitians into zombies. For 10 points, name this toxin from Japanese *fugu*, or pufferfish, that blocks voltage-gated sodium channels, causing paralysis.

ANSWER: tetrodotoxin [or TTX]