ADVANCED INTEGRATED SCIENCE

Directions:
PLEASE DO NOT OPEN THE EXAM BOOKLET UNTIL DIRECTED.

Be sure to fill in your name on the answer sheet both by printing it in the correct space and by filling in the corresponding letter in the spaces provided.

Use a #2 pencil only.

Carefully erase any errors, and do not make any extraneous marks on the answer sheet. Do NOT use White-Out on any portion of the answer sheet.

The test has 90 items that will be scored. You have 90 minutes in which to answer all the questions.

There is only one correct answer per question. Do not spend too much time on any one question. Do the items you find easier first, and then go back to those you find more difficult or time consuming during the time you have remaining. Your individual score will be computed on the basis of the number of correctly answered items. (There is no penalty for guessing.)

In addition to the periodic table, there are several subject-specific items below that you may find useful in answering certain questions. Be sure to read them immediately after you are told to begin. You may refer to them at any time during the test.

INFORMATION THAT MAY BE USEFUL IN SOLVING SOME PROBLEMS

1 calorie = 4.184 joules
1/f = 1/d₀ + 1/d₁
C = 2f
h/h₀ = d/d₀
E = hf
speed of light in vacuum = 3.0 × 10⁸ m/sec
Planck's constant, h = 6.63 × 10⁻³⁴ joule-sec
v = c √(1 - v²/c²)
Avogadro's Number = 6.02 X 10²³
Q = mcΔT
KEave = 1/2mv²
PEgrav = mgh
W = F X S
W = Vq
v_avg = s/t
s = v₀t + 1/2at²
v_f² = v_i² + 2as
v_f = v_i + at
c = faλ
P₁V₁/T₁ = P₂V₂/T₂
I = V/R
1 C = 6.25 X 10¹⁸ e⁻
D = M/V
v = fλ
P = W/t
Kf water = -1.86 °C/m
Kb water = 0.51°C/m

Universal gas constant: R = 8.31 kPa-liter/(mole-K) = 0.0821 atm-liter/(mole-K)
Multiple Choice
Identify the letter of the choice that best completes the statement or answers the question and place your selection ON THE ANSWER SHEET.

1. **BONE CANCER**
   *When breast cancer cells migrate to bone tissue, the cancer is generally fatal. Researchers have discovered that a protein called transforming growth factor beta (TGF-B) is involved in this process. The protein stops cells in the G1 stage and promotes differentiation and apoptosis. TGF-B can also convert effector T-cells into suppressor T-cells.*

1. The type of cell signaling described here is
   A) synaptic.  
   B) paracrine.  
   C) endocrine.  
   D) inflammatory.  
   E) neuromodulatory.

2. If a cancerous cell mutates so that it can no longer receive the TGF-B signal, then
   A) the cells would proliferate.  
   B) the cells would self-destruct.  
   C) the cells would synthesize their DNA.  
   D) the cells would migrate to other sites.  
   E) the cells would attack neighboring cells.

3. The effect of TGF-B on T cells would cause
   A) an increase in the inflammatory response.  
   B) an increase in the cell-mediated response.  
   C) a decrease in the inflammatory response.  
   D) a decrease in the cell-mediated response.  
   E) an increase in both the inflammatory and cell-mediated response.

4. The action of TGF-B on the normal cell is similar to a
   A) tumor-promoter gene.  
   B) tumor-suppressor gene.  
   C) both a tumor-promoter and a tumor-suppressor gene.  
   D) neither a tumor-promoter nor tumor-supressor gene.  
   E) it cannot be determined from the information given.

5. The most obvious next step for researchers is to find ways to
   A) block cell receptors for TGF-B.  
   B) increase cell production of TGF-B.  
   C) mutate TGF-B genes in animal models.  
   D) mimic the action of TGF-B on bone cells.  
   E) remove the suppressor T cells from the bone tissue.

6. TGF-B is a protein that is chain of 380 amino acids. What kind of bond connects these amino acids together?
   A) ionic  
   B) ester  
   C) hydrogen  
   D) peptide  
   E) ether linkage

7. An amino acid consists of which functional groups?
   A) -N and -H  
   B) -NH and -OH  
   C) -NH₃ and -OH  
   D) -NO₂ and -COOH  
   E) -NH₂ and -COOH
8. Cis-platin is a compound used in chemotherapy for some kinds of cancer. It consists of hydrogen, 2.02%, nitrogen, 9.34%, chlorine, 23.6%, and platinum, 65.0%. What is the formula of this compound?

A) Pt₆Cl₂H₂N₆  
B) Pt₁₂Cl₁₂HN₅  
C) Pt₃H(NCl)₃

D) (PH)₆(NCl)₂  
E) PtCl₂(NH₃)₂

9. Amino acids can act as cellular fluid buffers. This means that the

A) amino group neutralizes bases, and the carboxalate neutralizes acids  
B) amino group neutralizes acids, and the carboxalate neutralizes bases  
C) lowers the activation energy in the Kreb’s Cycle  
D) acts as an intermediate in an enzymatic system  
E) amino acid is a zwitterion

II. DIAMONDS

Diamonds have been revered for their beauty and rarity for centuries. From myths about valleys of diamonds protected by snakes, to the production of millions of carats in rough diamonds each year, the history of diamonds is one of mystical power, beauty and commercial expertise. The first recorded history of the diamond dates back some 3,000 years to India, where it is likely that diamonds were first valued for their ability to refract light. In those days, the diamond was used in two ways-for decorative purposes, and as a talisman to ward off evil or provide protection in battle. In modern times it has inspired countless songs, novel, movies, and, unfortunately, wars.

10. What type of bonding is found in diamonds?

A) sp  
B) sp²  
C) sp³

D) sp⁴  
E) ionic

11. Natural diamonds are formed under what conditions?

A) low temperature, low pressure  
B) low temperature, high pressure  
C) high temperature, low pressure  
D) high temperature, high pressure  
E) high velocity impacts by meteorites on the earth’s surface

12. What are the two conductive properties of diamonds?

I. electrical insulator  
II. electrical conductor  
III. thermal insulator  
IV. thermal conductor

A) I & III  
B) I & IV  
C) II & III  
D) II & IV  
E) varies depending on the size of the diamond

13. Natural color in diamonds is due to:

A) impurities of iron, copper, and nickel.  
B) impurities of nitrogen, hydrogen, or boron.  
C) voids created by cationic – anionic interactions.  
D) structural stresses created in cutting them to shape.  
E) irradiation by uranium atoms trapped in the crystal structure.
14. Diamonds are commonly mined via open-pit mines. Which of the following is NOT a common negative environmental impact of open-pit mines?
   A) lowering of water table
   B) acid mine drainage
   C) habitat destruction
   D) ground subsidence
   E) tailings piles

15. Which of the following would be the most likely formation in which to find diamonds?
   A) Volcanic plumes
   B) Sedimentary rock
   C) Metamorphic rock
   D) Fast-flowing streams
   E) Shallow lake bottoms

16. When light from the air enters a diamond at an angle of less than 90° to the normal, the angle of refraction
   A) is equal to the angle of incidence.
   B) is less than the angle of incidence.
   C) is greater than the angle of incidence.
   D) can be less or greater than the angle of incidence depending upon the size.
   E) can be less or greater than the angle of incidence depending upon the number of facets.

17. When compared to cubic zirconium (a synthetic gemstone resembling diamond)
   I. diamonds are harder
   II. diamonds have greater refractive index
   III. diamonds are denser
   
   A) I only
   B) II only
   C) III only
   D) I and II only
   E) I, II and III

III. HYDROELECTRIC PUMPED STORAGE

Hydroelectric Pumped Storage is a way to store water at an elevation so it can be used to provide electricity at times of larger than ordinary demand. Water is pumped from a lower elevation reservoir to an upper reservoir during times of less than average demand, times when electric supply grids have surplus capacity. It flows back through a generator to the lower reservoir during times when there is an above average demand for electric energy. The method allows electric grid operators to compensate for the variability in demand throughout the day and season. Of the electric power delivered in the United States about 2.5 percent of it goes through some form of storage almost all of which is pumped storage. In the United States the equipment is designed to function as a motor and pump in one direction of rotation and as a turbine and generator in opposite rotation.

The Yard’s Creek Pumped Storage Facility located in Blairstown, NJ has a maximum 400 MW total plant capacity. The upper reservoir holds approximately $6.2 \times 10^6$ m$^3$ of water. Maximum flow rate of the water is about 250 m$^3$/s. It flows through a 549 m long pipe which is 0.457 m in diameter. The density of water is 1000 kg per m$^3$.

18. The storage of energy by the pumped storage method is in a ___ form.
   A) nuclear
   B) Martinized
   C) kinetic energy
   D) chemical energy
   E) potential energy
19. The pumped storage method for storing energy is only 70 to 85 percent efficient. Given four possible reasons for loss in efficiency.
   I. Pumping is not 100% efficient.
   II. Generators are not 100% efficient.
   III. Some water evaporates, depending on surface area and temperature.
   IV. Combined pumps and generators are more than 100% efficient.

Which are true statements?
A) all four  D) only II and III
B) only I and II  E) only I, II and III
C) only I and III

20. At the Yard’s Creek facility if the operation were 100% efficient and it were operating at maximum output, the elevation change of the water would be approximately ___ m.
   A) 170  B) 250  C) 333  D) 439  E) 549

21. If half the water from the upper reservoir at the Yard’s Creek facility could be drained to the lower reservoir, the maximum electric power output could be maintained for approximately ___.
   A) 1.2 seconds  D) 5.1 days
   B) 21 minutes  E) a week
   C) 3.4 hours

22. What factor(s) influence how fast a liquid will flow through a pipe?
   I. hydrogen bonding
   II. temperature
   III. molecular shape
   IV. whether the molecule is organic or inorganic
   A) I & II only  D) I, III & IV only
   B) I & III only  E) all of them
   C) I, II & III only

23. What is the energy consumed by H₂O if this movement changes its temperature by 0.5°C?
   A) -2.1×10³ kJ  B) 2.1×10³ kJ  C) 1.3×10⁶ kJ  D) 1.3×10⁹ kJ  E) 2.6×10⁹ kJ

24. Pumped storage hydroelectric is favored compared to other storage methods because;
   I. cheaper to build
   II. quickly brought on line when needed
   III. water can be reused
   IV. stores the most energy
   A) I and II  D) II and III
   B) II and III  E) all selections
   C) I and IV

25. Another method of storage would be to decompose water.
   \[ 2\text{H}_2\text{O} \rightarrow 2\text{H}_2 + \text{O}_2 \quad \Delta H = +286 \text{ kJ/mol H}_2\text{O} \]
   How much energy would be required to decompose a cubic meter (m³) of water?
   A) -2.8×10⁸ kJ  D) 1.6×10⁷ kJ
   B) -1.6×10⁷ kJ  E) 2.8×10⁵ kJ
   C) 5.1 kJ
26. What other issues would need to be addressed to use this as a storage method?
   I. storage of H$_2$
   II. storage of O$_2$
   III. chemical reaction efficiency
   IV. impurities in the water

   A) I   D) I and II
   B) II   E) III and IV
   C) III

27. From the information in Table 1, one reason for the differences in abundance and types of species found in the lower reservoir versus the auxiliary (upper) reservoir would be the _________ of the fish.

   A) habitat   D) food requirements
   B) lifespan   E) reproductive habits
   C) adult size

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Table 1. Species composition and relative abundance of fish collected during the 2009 boat electrofishing surveys in the Project area. (http://ka.sharepointsite.net/YardsCreek/public/Initial%20Study%20Report/Aquatic%)

<table>
<thead>
<tr>
<th>Species</th>
<th>Lower Reservoir</th>
<th>Auxiliary Reservoir</th>
<th>Nest builder?</th>
<th>habitat</th>
<th>food</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Relative Abundance</td>
<td>Number</td>
<td>Relative Abundance</td>
<td></td>
</tr>
<tr>
<td>Bluegill</td>
<td>1</td>
<td>0.2%</td>
<td>342</td>
<td>63.0%</td>
<td>littoral Algae, aquatic insects</td>
</tr>
<tr>
<td>Brown Bullhead catfish</td>
<td>1</td>
<td>0.2%</td>
<td>1</td>
<td>0.2%</td>
<td>benthic Molluscs, insects, algae</td>
</tr>
<tr>
<td>Chain Pickerel</td>
<td>2</td>
<td>0.5%</td>
<td>8</td>
<td>1.5%</td>
<td>no littoral Small fish, frogs</td>
</tr>
<tr>
<td>Killifish</td>
<td>1</td>
<td>0.2%</td>
<td>0</td>
<td>0.0%</td>
<td>Some species littoral Aquatic insects</td>
</tr>
<tr>
<td>Largemouth Bass</td>
<td>11</td>
<td>2.5%</td>
<td>160</td>
<td>29.5%</td>
<td>yes littoral Crayfish, fish, other bass</td>
</tr>
<tr>
<td>Pumpkinseed</td>
<td>4</td>
<td>0.9%</td>
<td>26</td>
<td>4.8%</td>
<td>yes littoral Small prey</td>
</tr>
<tr>
<td>Rock Bass</td>
<td>1</td>
<td>0.2%</td>
<td>0</td>
<td>0.0%</td>
<td>yes Rocky littoral Aquatic insects</td>
</tr>
<tr>
<td>Smallmouth Bass</td>
<td>89</td>
<td>20.6%</td>
<td>1</td>
<td>0.2%</td>
<td>yes varies Small prey</td>
</tr>
<tr>
<td>Yellow Perch</td>
<td>323</td>
<td>74.6%</td>
<td>5</td>
<td>0.9%</td>
<td>no littoral Small prey, fish</td>
</tr>
<tr>
<td><strong>Total Catch</strong></td>
<td><strong>433</strong></td>
<td><strong>100%</strong></td>
<td><strong>543</strong></td>
<td><strong>100%</strong></td>
<td></td>
</tr>
</tbody>
</table>
28. What can be deduced about the water levels of the lower and auxiliary reservoirs?
   A) Both reservoir water levels are held constant.
   B) The water levels of both reservoirs vary occasionally.
   C) The water levels of both reservoirs vary consistently.
   D) Only the lower reservoir water level varies consistently.
   E) Only the auxiliary reservoir water level varies consistently.

29. The top predator in these ecosystems is most likely the
   A) bluegill.
   B) killifish.
   C) rock bass.
   D) chain pickerel.
   E) brown bullhead catfish.

IV. GUANO
John Maron (2006) studied the effect of introduced species on the ecosystems of the Aleutian Islands of Alaska. Historically, these islands were the home to millions of seabirds. Bird guano supported the growth of dense stands of graminoid grasses. Arctic foxes were introduced in the early 1900’s to create a base for fur trading. Norway rats also migrated there from various ships. The US Fish and Wildlife Service removed the foxes from many islands by the 1980’s. Maron compared islands that had never had foxes with islands that had had their foxes removed. His findings are summarized in Table 1 below. Lifestyle information about the animals is found in Table 2.

<table>
<thead>
<tr>
<th>parameter</th>
<th>Historically Fox-free islands</th>
<th>Islands with foxes removed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of seabirds</td>
<td>687,812 +/- 399,909</td>
<td>15,867 +/- 5289</td>
</tr>
<tr>
<td>Graminoid biomass g/m²</td>
<td>361 +/- 9</td>
<td>5 +/- 7</td>
</tr>
<tr>
<td>% cover by graminoids</td>
<td>45 +/- 7</td>
<td>10 +/- 5</td>
</tr>
<tr>
<td>Dominant vegetation</td>
<td>graminoids</td>
<td>Mosses, lichens, shrubs</td>
</tr>
</tbody>
</table>

Table 2. Lifestyle information for representative Aleutian Island animals

<table>
<thead>
<tr>
<th>animal</th>
<th>Gestation/incubation period (days)</th>
<th>Litter size</th>
<th>Litters/yr.</th>
<th>Age at sexual maturity</th>
<th>Lifespan (yrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arctic fox</td>
<td>53</td>
<td>5-25</td>
<td>1</td>
<td>10 months</td>
<td>3</td>
</tr>
<tr>
<td>Norway rat</td>
<td>21-23</td>
<td>6-12</td>
<td>24-6</td>
<td>3 months</td>
<td>2-3</td>
</tr>
<tr>
<td>Puffin (seabird)</td>
<td>74</td>
<td>1</td>
<td>1</td>
<td>3-5 years</td>
<td>15-40</td>
</tr>
</tbody>
</table>

30. The population of seabirds was lower on islands with foxes removed because
   A) the seabirds had a K-strategist style.
   B) the seabirds had lost their food source.
   C) the seabirds had lost their nesting sites.
   D) the rats were still present on those islands.
   E) human interference had caused the seabirds to migrate away.

31. Bird guano is an important source of
   I. carbon
   II. nitrogen
   III. phosphorus
   IV. sulfur

   A) I and II
   B) II and III
   C) 3 of the above
   D) all of the above
   E) only one of the above.
32. The birds most vulnerable to predation by the foxes and rats would have been
   A) seed eaters.                               D) migratory birds.
   B) ground nesters.                           E) brightly colored birds.
   C) predatory birds.

33. Loss of the birds affected the graminoid grasses because
   A) the birds fertilized the graminoids.
   B) the birds were pollinators of the graminoids.
   C) the birds spread the seeds of the graminoids.
   D) the foxes and rats tunneled under the graminoids, destroying their roots.
   E) the foxes and rats preyed upon the graminoids after the birds were extinct.

34. The islands with foxes removed had _______ species richness compared to the historically fox-free islands because __________.
   A) increased ….of competitive release.
   B) increased … of decreased predation.
   C) equal …of removal of invasive foxes.
   D) decreased… of competitive inhibition
   E) decreased… of soil nutrient depletion.

35. Which of the following nutrient cycles is primarily a sedimentary cycle?
   A) the rock cycle.                               D) the nitrogen cycle.
   B) the water cycle.                              E) the phosphorus cycle.
   C) the carbon cycle.

36. Maron also studied the concentration of nitrogen (nitrates) in the soils of the islands. He measured this because
   A) nitrogen is a toxic substance for many plants.
   B) nitrogen is an indicator of species biodiversity.
   C) nitrogen is a limiting factor for terrestrial systems.
   D) nitrogen is an indicator of the presence of rats and foxes.
   E) nitrogen enrichment is common in disturbed communities.

37. In major productive agricultural areas of the USA, which of the following are anthropogenic sources of soil nitrogen?
   I. fertilizers
   II. burning coal
   III. burning gasoline
   IV. dairy farms
   A) I and II.                                      D) all of the above.
   B) II and III.                                    E) only one of the above.
   C) 3 of the above.

38. Some garden or lawn fertilizer comes in bags labeled 5-10-10. This set of numbers refer to the
   A) expiration date of the fertilizer.
   B) settings for your lawn spreader.
   C) ratio of fertilizer, water, and seed.
   D) interval, in days, of when it has to be reapplied.
   E) percentage of nitrogen-phosphorus-potash in the mixture.

39. The smell of freshly cut grass is mainly due to cis-3-hexenal. How many double bonds are found in this molecule?
   A) none  B) 1  C) 2  D) 3  E) 6

40. Guano also contains some oxalic acid, a diprotic organic acid. Which formula best represents this molecule?
Cystic fibrosis is an autosomal recessive, lethal genetic disorder occurring in 1 of every 2500 European and American Caucasian children. People with cystic fibrosis create mucus that is very thick and sticky. The gene responsible (cystic fibrosis transmembrane regulator or CFTR) normally creates chloride ion channels in cell membranes. These channels are important for removing bacteria and mucus, helping enzymes mix with food, and conserving salt.

Scientists have wondered why this lethal mutation has persisted so long in these Caucasian populations. One hypothesis links the mutant gene with the ability to survive the lethal strain of Cholera. Vibrio cholera causes extreme diarrhea by opening all transmembrane chloride ducts in the small intestine. Another hypothesis notes that Salmonella typhi, the bacterium that causes typhoid fever, uses the normal CFTR protein for entry into the gastrointestinal tract.

41. Which of the following organ systems would be expected to have high expression of the CFTR gene?
   i. the respiratory system
   ii. the digestive system
   iii. the sweat glands
   iv. the nervous system

   A) I and II only       D) all of the above
   B) II and III only    E) Only 3 of the above
   C) II and IV only

42. A cell physiologist tested the cholera hypothesis with a mouse model that carried the CFTF mutation. The results were that
   A) male CF mice died from cholera.
   B) homozygous dominant mice survived cholera.
   C) homozygous recessive mice died from cholera.
   D) heterozygous mice secreted half the expected amount of fluid.
   E) there was no significant difference in survival based upon genotype.

43. Cystic fibrosis is rare in Blacks, Hispanics and Asians. It is estimated that 1 of 8100 Blacks are born with CF. What is the approximate frequency of carriers in the Black population?
   A) 0.011       D) 0.0023
   B) 0.022       E) there is not enough information
   C) 0.0011

44. If the frequency of CFTR heterozygotes is 1/150 in the Asian population, what is the probability that a child born of a Caucasian mother and an Asian father will have CF?
   A) 0       D) 0.25
   B) 0.0001   E) 0.75
   C) 0.0002
45. One explanation for the fact that the CFTR mutation is less frequent in the Hispanic, Black, and Asian populations is that
A) this is an example of genetic drift.
B) these populations were at greater risk for intestinal diseases.
C) the thicker mucus in heterozygotes conferred an advantage at high altitudes.
D) the loss of salt due to sweat in heterozygotes is a disadvantage in hot climates.
E) these three populations had cleaner water sources and did not need the CFTR mutation.

46. The best argument against the hypothesis that the CFTR mutation confers an adaptive advantage for heterozygotes against cholera is that
A) cholera is a disease found only in Africa.
B) human CF heterozygotes have a lessened life span.
C) the mouse model did not display the same advantage.
D) cholera epidemics in Europe began during the Industrial Revolution.
E) lethal recessive mutations eventually are removed from a population by natural selection.

47. The CFTR protein is in the ATP-binding cassette (ABC) family. This means that the movement of chloride through the channel is a type of
A) osmosis.
B) co-transport.
C) active transport.
D) simple diffusion.
E) facilitated diffusion.

48. The mutation in the CFTR is a deletion three nucleotides that results in a loss of the amino acid phenylalanine at the 508th position on the protein. Which represents phenylalanine?

A) 

B) 

C) 

D) 

E) 

49. People with CF have less thiocyanate and hypochlorite in their saliva. What are the formulas of these ions?
A) TiCy\(^{1-}\), HTiCy\(^{1-}\).
B) SCN\(^{1-}\), OSCN\(^{1-}\).
C) SCNO\(_3\)\(^{1-}\), HSCNO\(_2\)\(^{1-}\).
D) CN\(^{1-}\), HCN\(^{1-}\).
E) CNO\(_3\)\(^{1-}\), CNO\(^{1-}\).
50. The most common non-pulmonary complication of cystic fibrosis is diabetes. This is due to damage to the pancreas. Thus, less of the_____,______ is produced.

A) digestive juice, bile  
B) protein, insulin  
C) enzyme, amylase  
D) vitamin, ascorbic acid  
E) neurotransmitter, serotonin

**VI. ROCKET**

On March 4, 2011 the NASA Glory mission carrying the Total Irradiance Monitor (TIM); and the Aerosol Polarimetry Sensor (APS) was launched on a Taurus XL rocket from the Vandenberg Air Force Base. A protective covering called a fairing failed to separate, and the rocket that was to carry the satellite was unable to accomplish its mission.

51. Several factors contribute to the difficulty of achieving orbit. Which of these is most dependent on the additional mass of the fairing?

A) the rate of fuel burned  
B) the inertia of the rocket  
C) the thrust force provided by the rocket  
D) the extra force of gravity on the rocket  
E) the drag force exerted by the atmosphere

52. In terms of the planet's mass M, the rocket's mass m, the planet's radius R, and the universal gravitational constant G, which equation would be used to calculate the escape speed, which is the speed needed to escape from a gravitational field without further propulsion, from a planet?

A) \( \frac{mv^2}{R} = \frac{GMm}{R^2} \)  
B) \( \frac{mv^2}{R} = mG \)  
C) \( \frac{1}{2}v^2 = GM/R \)  
D) \( \frac{1}{2}mv^2/R = GMm \)  
E) \( \frac{1}{2}mv^2 = GMm/R^2 \)

53. The escape speed from Earth’s gravitational field 11.2 km/s. In order for the payload to be inserted into low earth orbit the velocity after the burnout of stage 3

A) must be exactly 11.2 km/s.  
B) must be less than 11.2 km/s.  
C) must be greater than 11.2 km/s.  
D) will be either greater or less than 11.2 km/s depending upon the mass of the rocket.  
E) will be either greater or less than 11.2 km/s depending upon the trajectory of the rocket.

54. Earth’s surface gravity is 9.8 m/s\(^2\) and the moon’s surface gravity is 1.6 m/s\(^2\). If an astronaut had a mass of 50 kg on earth her mass on the moon would be

A) 8.2 kg.  
B) 41.8 kg.  
C) 50 kg.  
D) 300 kg.  
E) 410 kg.

55. In low earth orbit Earth’s gravitational acceleration for the satellite

A) is 0 m/s\(^2\).  
B) is 9.8 m/s\(^2\).  
C) is greater than 9.8 m/s\(^2\). 
D) is less than 9.8 m/s\(^2\), but greater than 0 m/s\(^2\).  
E) depends upon the mass of the rocket.
56. The orbital velocity for a satellite in elliptical orbit
   A) is greatest at apogee (the point most distant from the Earth).
   B) is greatest at perigee (the point closest to the Earth).
   C) is greatest at some point between apogee and perigee.
   D) is greatest at some point between perigee and apogee.
   E) is the same at apogee and perigee.

57. The Taurus delivery system has the capability to spin the payload with an angular rate of 0 to 355 degrees per second prior to deployment. The actual spin rate depends on the
   I. payload mass
   II. center of gravity
   III. composition of the payload
   A) I only
   B) II only
   C) III only
   D) I and II only
   E) I, II and III

58. As a satellite is deployed and its solar panels are extended, its spin rate
   A) increases
   B) decreases
   C) remains the same
   D) increases, then decreases
   E) decreases, then increases

VII. OIL SPILL

A newly discovered type of oil-eating microbe is suddenly flourishing in the Gulf of Mexico and gobbling up the BP spill at a much faster rate than expected, scientists reported. Also, the microbe works without significantly depleting oxygen in the water... A report just last week described a 22-mile-long underwater mist of tiny oil droplets. They found that the dominant microbe in the oil plume is a new species, closely related to members of Oceanospirillales. This microbe thrives in cold water, with temperatures in the deep recorded at 5°C (41°F).

Researcher Terry Hazen, a microbial ecologist at Lawrence Berkeley National Lab in Berkeley, California, said that within two weeks of the capping [of the oil rig], the plume could not be detected, but there was a phenomenon called marine snow that indicated microbes had been feasting on hydrocarbons.

Adapted From http://www.msnbc.msn.com/id/38834330/ns/disaster_in_the_gulf/

59. These findings are in stark contrast with the prolonged presence of oil after the Exxon Valdez oil spill in Alaska. Why might there be more oil-eating microbes in the Gulf than in Alaskan waters?
   A) Alaskan waters have lower iron levels than Gulf waters.
   B) Alaskan waters are too cold for these microbes to survive.
   C) Oil-eating microbes are consumed by Alaskan fish, such as salmon.
   D) Oil companies planted these microbes in an effort to mitigate the effects of oil spills.
   E) Periodic leaks and natural seeps of oil in the Gulf have caused the evolution of oil-eating microbes.

60. Common effects of ocean oil spills include all of the following EXCEPT:
   A) Algal/phytoplankton blooms
   B) Destruction of shoreline habitat
   C) Death of sea birds and mammals
   D) Contamination of commercial fishing stock
   E) Respiratory and intestinal diseases in workers.

61. Scientists also had been concerned that oil-eating activity by microbes would quickly
A) create an anoxic dead zone.
B) interfere with other clean-up efforts.
C) out-compete normal ocean microbes.
D) contaminate organisms higher in the food chain.
E) release greater quantities of ozone-depleting gases.

62. Why is it significant that the oil plume was in a “mist of tiny oil droplets”?
A) This finding showed that microbes were already at work.
B) This finding meant that the rig had been effectively capped.
C) This finding showed that the oil was still present in the Gulf.
D) This finding meant that microbes could work more efficiently.
E) This finding meant that less oil had been spilled than previously announced.

63. Scientists hypothesized that the microbes needed iron from the seawater in order to degrade the oil. One reason for this hypothesis is that
A) iron helps to maintain the low temperatures required by these microbes.
B) iron is needed to attract magnetic components of crude oil.
C) iron is needed for the microbes to replicate their DNA.
D) iron is needed for hydrocarbon degrading enzymes.
E) iron is needed for microbial protein synthesis.

64. Various chemical dispersants were used to treat the oil spill. What is the nature of these dispersants?
A) They are both polar and non-polar.
B) They are non-polar molecules so they can dissolve in the oil.
C) They are highly polar molecules so that they can dissolve in water.
D) They chemically react with the oil molecules and decompose them into tiny fragments.
E) They are ionic molecules that allow the salt in the sea water to coat the surface of the oil droplets.

65. What happened to most of the petroleum that reached the surface?
A) It evaporated into the atmosphere
B) It was picked up by boats using skimmers.
C) It is still in the Gulf of Mexico as giant oil slicks.
D) It floated on the Gulf Stream out into the Atlantic Ocean.
E) It came ashore onto the beaches and into the tidal marshes and was removed by shore workers.

66. Petroleum is considered sweet if
A) the drilling well erupts as a gusher.
B) it contains large amounts of aromatics.
C) it contains a higher percentage of octane.
D) has a low percentage of sulfur compounds.
E) it is pumped from a land based well rather than from an ocean platform well.

67. Petroleum is refined in order to:
I. remove unwanted sulfur
   II. separate it into its useful components
   III. break large hydrocarbon molecules into smaller ones
   IV. mix engine performance additives into the gasoline
A) I & II only
B) I & IV only
C) II & III only
D) I, II, & III only
E) all 4

68. Which most affects the density of the water at the depth of the wellhead?
I. temperature
II. pressure
III. light

A) I only  
B) II only  
C) III only  
D) I and II only  
E) I, II and III

VIII. NSAIDs
NSAIDs are nonsteroidal anti-inflammatory drugs with analgesic (pain-reducing), antipyretic (fever-reducing), and anti-inflammatory effects. As analgesics, NSAIDs are unusual in that they are non-narcotic. The most prominent members of this group of drugs are aspirin (acetylsalicylic acid or ASA), ibuprofen (Advil, Motrin, Nuprin, etc.) and naproxen (Aleve, Midol Extended Relief, Naprosyn, etc.). All can be purchased OTC or over-the-counter, i.e., no doctor’s prescription is required. The structures for the three are below. Acetaminophen (Anacin, PediaCare, Tylenol, etc.) has analgesic and antipyretic effects but is not a very good anti-inflammatory.

69. Aspirin, ibuprofen, and naproxen are generic drugs. This means that they:
A) are derived from natural sources.
B) are mostly taken by elderly (geriatric) patients
C) were first made many generations ago
D) are available to the general public through Medicare
E) can be made by any pharmaceutical company after the original brand-name drug patent has expired.
70. In 1897, Felix Hoffmann, working for Bayer AG in Germany, first produced aspirin from salicylic acid. What functional group is found in aspirin?

A) aldehyde  
B) amino  
C) ester  
D) ether  
E) ketone

71. NSAIDs act in a cell by being competitive inhibitors of the enzyme cyclooxygenase (COX). What does this mean?

A) A NSAID molecule will fill the active site in COX instead of the normal substrate.  
B) They work faster than COX.  
C) The normal substrate of COX is prevented from being made.  
D) NSAIDs denature COX by competing with the formation of hydrogen bonds.  
E) The substrate of COX is locked in the active site by the NSAID molecules and prevented from leaving.

72. Research has shown that L-ibuprofen is an effective pain reliever but D-ibuprofen is not at all effective. What generalization can be drawn from this information?

A) Only the L-isomer can be microencapsulated for use in pills. This difference in packaging is responsible for differences in biochemical activity.  
B) These two structural isomers behave exactly the same in biological systems, but only L-ibuprofen blocks the pain signal.  
C) The difference in behavior illustrates the molecular specificity of a substrate for its binding site.  
D) The L-isomer is heavier than the D-isomer, and biochemical activity is related to the molecular weight of a drug.  
E) Only the L-isomer is found in nature, so adaptations for use of the D-isomer have not evolved.

73. There are 2 COX enzymes. COX1 is active in the stomach lining, platelets and kidney function. COX2 is active in inflamed tissues. Expected side-effects of overuse of NSAIDs include which of the following:

I. ulcers  
II. prolonged bleeding  
III. weight gain  
IV. swelling

A) Only one of the above.  
B) I and II.  
C) I and III.  
D) III and IV.  
E) Three of the above.

74. A probable action for COX2 is

A) participation in release of prostaglandins.  
B) participation in the cellular respiration pathways.  
C) interference with protein synthesis.  
D) interference with antibody-antigen recognition.  
E) interference with propagation of the action potential.

75. Ibuprofen (patented in 1961) and naproxen (patented in 1976) act essentially the same because they:

I. have similar size and shape  
II. have similar functional groups  
III. have similar molar masses  
IV. are both obtained from natural materials.

A) IV only  
B) I & II only  
C) I, II, & III only  
D) I, II, & IV only  
E) all of them
IX. NUCLEAR FISSION

Nuclear fission is the process whereby a heavy nucleus captures a slow moving neutron and undergoes splitting into smaller daughter nuclei. American designed nuclear reactors use “fuel rods” that are about 4 or 5 % uranium 235. The daughter products of the fission are radioactive and typically continue to decay. Control rods absorb neutrons and thereby control the number of neutrons available to cause fission. They are in the fuel rod reactor area. The farther into the core they are inserted, the more neutrons they absorb. Spent fuel rods are usually stored in pools of water after removal from a reactor core.

76. In an atom of the electrically neutral isotope of uranium, $^{238}\text{U}$ (chemical valence +6) there are ____ electrons.
   A) 327   B) 235   C) 143   D) 92   E) 6

77. Moderators thermalize or slow neutrons (control the neutron’s speed) through a series of collisions of the neutrons and the moderator material. Which of the following five materials would be the best moderator? ____
   A) water   D) cadmium
   B) steel   E) aluminum
   C) boron

78. Given three statements about spent or used fuel rods:
   I. Heat is produced in radioactive decay
   II. Radiation is still being produced
   III. The rods are hot in temperature, but require a handler just to wear asbestos gloves.

Spent fuel rods are referred to as “hot” because ____
   A) I only   D) only I and II
   B) II only   E) only I and III
   C) only III

79. In the fuel rod an atom of uranium $\text{U}^{238}$ absorbs a neutron and subsequently emits a beta particle ($^{0}\text{e}$) becoming neptunium. This then emits a beta particle and becomes plutonium. The mass of the atom of plutonium is ____ the original mass of the uranium $\text{U}^{238}$.
   A) half   D) more than
   B) double   E) the same as
   C) less than

80. Evidence has been found that about 1.7 billion years ago there had been some “naturally occurring nuclear reactors” when the uranium ore was about 3% $\text{U}^{235}$. Uranium ore today is about 99.3% $\text{U}^{238}$ and 0.7% $\text{U}^{235}$. The half-life of $\text{U}^{235}$ is approximately 700 million years. (ignore the isotope $\text{U}^{234}$ for this problem). The half-life of $\text{U}^{238}$ is approximately ____ that of $\text{U}^{235}$.
   A) 0.1   B) 0.5   C) 1   D) 5   E) 100

81. The International Atomic Energy Association has been closely monitoring the release of radionuclides at the Fukushima Dai-Ichi Nuclear Power Station. One of the isotopes that is being tracked is $\text{Cd}^{106}$. Why is this?
   A) It indicates that there is a possible core meltdown.
   B) It indicates the level of power left in the back-up batteries.
   C) Cadmium is a rare and expensive metal that will be hard to replace if lost.
   D) $\text{Cd}^{106}$ is a high energy gamma ray emitter that is especially hazardous to humans.
   E) The containment building housing the reactor is lined with cadmium, a strong X-ray absorber.
82. One of the products of the fission of U-235 can be some I-131. I-131 has a half-life of slightly over 8.0 days. How many days would it take to reduce the I-131 to 10% of the original amount? 
A) 15.2 days  D) 32.0 days
B) 16.0 days  E) can not be determined unless you know the original amount of I-131.
C) 26.7 days

83. I-131 undergoes decay by beta (β) emission. What is the daughter nuclide?
A) I-130  D) Sb-127
B) I-132  E) Te-132
C) Xe-131

84. The Dai-Ichi Nuclear Power Station had at least two hydrogen explosions. What is the source of this hydrogen gas?
A) Hydrogen is used as a fuel in the fusion process.
B) Hydrogen is a by-product of the fission process.
C) Hydrogen gas is used as the coolant in the reactor.
D) At high temperatures, water will decompose into its elements.
E) Hydrogen is used to enrich the uranium fuel by changing U-235 into U-238.

85. Plutonium is another fuel used in nuclear power plants. Pu-240 has a half-life of 6561 years. What is its rate constant? Eliminated
A) 1.06x10^-3 M^-2 yr^-1
B) 1.06x10^-2 M^-2 yr^-1
C) 4.55x10^-3 M^-2 yr^-1
D) 4.55x10^-2 M^-2 yr^-1
E) 9.47x10^-3 M^-2 yr^-1

86. One advantage of generating power from nuclear power plants as opposed to coal power plants is
A) nuclear power plants create fewer toxic residues.
B) the United States has more uranium reserves than coal reserves.
C) nuclear power plants are cheaper to build and operate than coal plants.
D) less CO2 is generated as a result of using nuclear power versus using coal.
E) a higher net energy yield is generated by nuclear plants than by coal plants.

87. After the earthquake in Fukushima, Japan, people in that area were advised to take iodine pills. These pills help protect against _______ cancer which may be caused by exposure to radiation.
A) skin  B) lung  C) colon  D) breast  E) thyroid

88. Which of the following is NOT an early symptom of radiation poisoning?
A) bleeding  B) diarrhea  C) nausea  D) fatigue  E) rashes

89. Nuclear power plants produce electricity by
A) heating steam to spin turbines.
B) concentrating ions to charge molten salt batteries.
C) generating x-rays, which accelerate electrons in wires.
D) channeling alpha particles to charge photovoltaic cells.
E) emitting high energy neutrons which charge magnetic sheets.

90. A partial meltdown occurred at the Fukushima power plant because the
A) tsunami swept through the pool of spent fuel rods.
B) backup electric power supply system was damaged.
C) earthquake cracked the walls of the containment building.
D) operators fled the damaged building to escape the tsunami.
E) reactor was working at a higher capacity to compensate for other damage.
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