



The 61st Annual
Merck State Science Day Competition
May 17, 2011

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

$$1 \text{ calorie} = 4.184 \text{ joules}$$

$$1/f = 1/d_o + 1/d_i$$

$$C = 2f$$

$$h_i/h_o = d_i/d_o$$

$$E = hf$$

$$\text{speed of light in vacuum} = 3.0 \times 10^8 \text{ m/sec}$$

$$\text{Planck's constant, } h = 6.63 \times 10^{-34} \text{ joule-sec}$$

$$v = c \sqrt{1 - v^2/c^2}$$

$$\text{Avogadro's Number} = 6.02 \times 10^{23}$$

$$Q = mc\Delta T$$

$$KE_{\text{ave}} = 1/2mv^2$$

$$PE_{\text{grav}} = mgh$$

$$W = F \times S$$

$$W = Vq$$

$$v_{\text{avg}} = s/t$$

$$s = v_o t + 1/2at^2$$

$$v_f^2 = v_i^2 + 2as$$

$$v_f = v_i + at$$

$$c = f\lambda$$

$$P_1V_1/T_1 = P_2V_2/T_2$$

$$I = V/R$$

$$1 \text{ C} = 6.25 \times 10^{18} \text{ e}^-$$

$$D = M/V$$

$$v = f \lambda$$

$$P = W/t$$

$$K_f \text{ water} = -1.86 \text{ }^\circ\text{C/m}$$

$$K_b \text{ water} = 0.51 \text{ }^\circ\text{C/m}$$

$$\text{Universal gas constant: } R = 8.31 \text{ kPa-liter/(mole-K)} = 0.0821 \text{ atm-liter/(mole-K)}$$

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 D) ground subsidence
 B) acid mine drainage E) tailings piles
 C) habitat destruction
15. Which of the following would be the most likely formation in which to find diamonds?
- A) Volcanic plumes D) Fast-flowing streams
 B) Sedimentary rock E) Shallow lake bottoms
 C) Metamorphic rock
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 D) I and II only
 B) II only E) I, II and III
 C) III only

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 $6.2 \times 10^6 \text{ m}^3$ of water. Maximum flow rate of the water is about $250 \text{ m}^3/\text{s}$. 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 D) chemical energy
 B) Martinized E) potential energy
 C) kinetic energy

26. What other issues would need to be addressed to use this as a storage method?
- I. storage of H₂
 - II. storage of O₂
 - III. chemical reaction efficiency
 - IV. impurities in the water

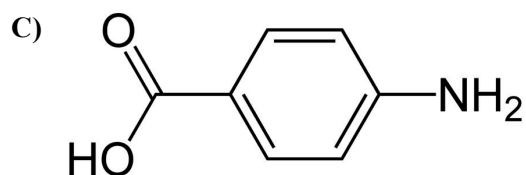
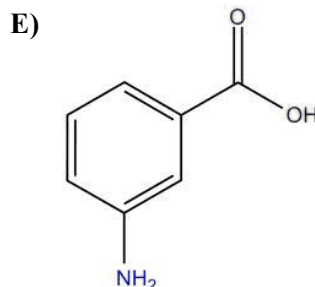
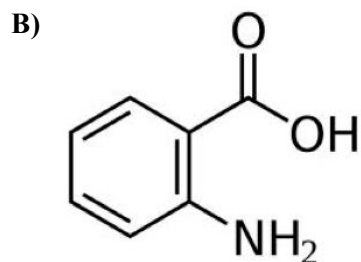
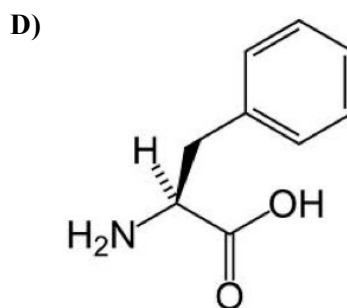
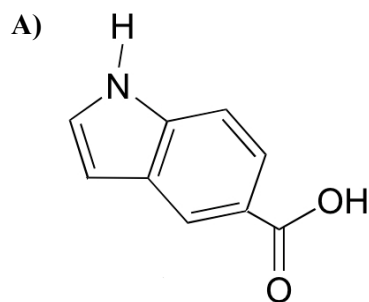
- A) I
- B) II
- C) III
- D) I and II
- E) III and IV

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%](http://ka.sharepointsite.net/YardsCreek/public/Initial%20Study%20Report/Aquatic%20Report))

Species	Lower Reservoir		Auxiliary Reservoir		Nest builder?	habitat	food
	Number	Relative Abundance	Number	Relative Abundance			
Bluegill	1	0.2%	342	63.0%	yes	littoral	Algae, aquatic insects
Brown Bullhead catfish	1	0.2%	1	0.2%	yes	benthic	Molluscs, insects, algae
Chain Pickerel	2	0.5%	8	1.5%	no	littoral	Small fish, frogs
Killifish	1	0.2%	0	0.0%	Some species	littoral	Aquatic insects
Largemouth Bass	11	2.5%	160	29.5%	yes	littoral	Crayfish, fish, other bass
Pumpkinseed	4	0.9%	26	4.8%	yes	littoral	Small prey
Rock Bass	1	0.2%	0	0.0%	yes	Rocky littoral	Aquatic insects
Smallmouth Bass	89	20.6%	1	0.2%	yes	varies	Small prey
Yellow Perch	323	74.6%	5	0.9%	no	littoral	Small prey, fish
Total Catch	433	100%	543	100%			

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

45. One explanation for the fact that the CFTR mutation is less frequent in the Hispanic, Black, and Asian populations is that
- this is an example of genetic drift.
 - these populations were at greater risk for intestinal diseases.
 - the thicker mucus in heterozygotes conferred an advantage at high altitudes.
 - the loss of salt due to sweat in heterozygotes is a disadvantage in hot climates.
 - 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
- cholera is a disease found only in Africa.
 - human CF heterozygotes have a lessened life span.
 - the mouse model did not display the same advantage.
 - cholera epidemics in Europe began during the Industrial Revolution.
 - 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
- osmosis.
 - co-transport.
 - active transport.
 - simple diffusion.
 - 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?



49. People with CF have less thiocyanate and hypothiocyanite in their saliva. What are the formulas of these ions?
- TiCy^{1-} , HTiCy^{1-}
 - SCN^{1-} , OSCN^{1-}
 - SCNO_3^{1-} , HSCNO_2^{1-}
 - CN^{1-} , HCN^{1-}
 - 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) $mv^2/R = GMm/R^2$
B) $mv^2/R = mG$
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
- is greatest at apogee (the point most distant from the Earth).
 - is greatest at perigee (the point closest to the Earth).
 - is greatest at some point between apogee and perigee.
 - is greatest at some point between perigee and apogee.
 - 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
- payload mass
 - center of gravity
 - composition of the payload
- I only
 - II only
 - III only
 - I and II only
 - I, II and III
58. As a satellite is deployed and its solar panels are extended, its spin rate
- increases
 - decreases
 - remains the same
 - increases, then decreases
 - 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?
- Alaskan waters have lower iron levels than Gulf waters.
 - Alaskan waters are too cold for these microbes to survive.
 - Oil-eating microbes are consumed by Alaskan fish, such as salmon.
 - Oil companies planted these microbes in an effort to mitigate the effects of oil spills.
 - 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:
- Algal/phytoplankton blooms
 - Destruction of shoreline habitat
 - Death of sea birds and mammals
 - Contamination of commercial fishing stock
 - 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?

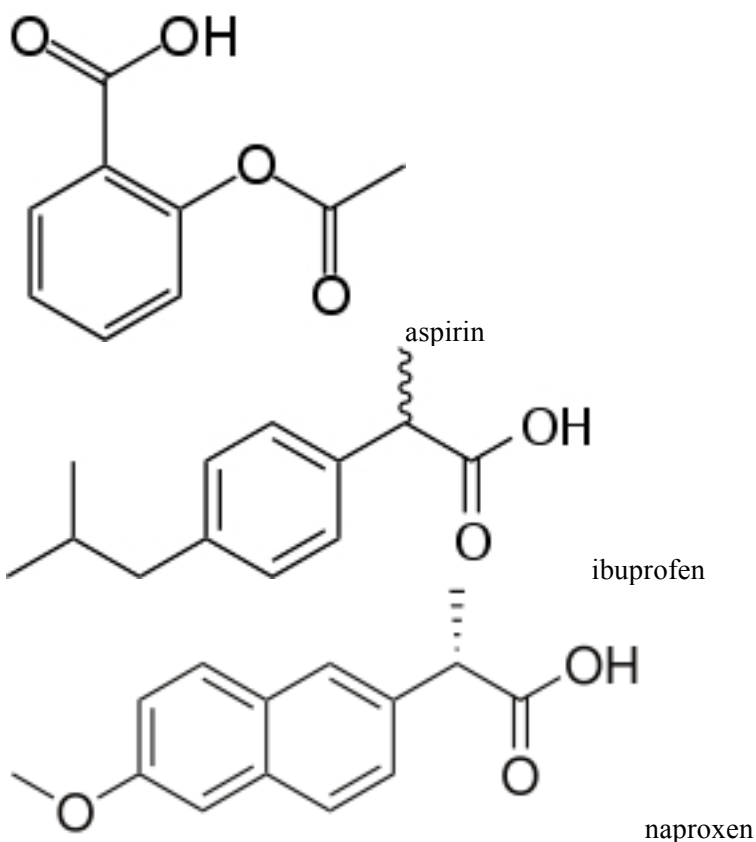
- I. temperature
- II. pressure
- III. light

- 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

Merck State Science Day 2011
Answer Section

ADVANCED INTEGRATED SCIENCE

MULTIPLE CHOICE

- | | | |
|-------|-------|-----------------------------|
| 1. B | 41. E | 81. A |
| 2. A | 42. D | 82. C |
| 3. C | 43. B | 83. C |
| 4. B | 44. C | 84. D |
| 5. A | 45. D | 85. A Eliminated |
| 6. D | 46. D | 86. E |
| 7. E | 47. C | 87. E |
| 8. E | 48. D | 88. E |
| 9. B | 49. B | 89. A |
| 10. C | 50. B | 90. B |
| 11. D | 51. C | |
| 12. B | 52. C | |
| 13. A | 53. B | |
| 14. D | 54. C | |
| 15. A | 55. B | |
| 16. B | 56. B | |
| 17. D | 57. D | |
| 18. E | 58. B | |
| 19. E | 59. E | |
| 20. A | 60. A | |
| 21. C | 61. A | |
| 22. C | 62. D | |
| 23. D | 63. D | |
| 24. A | 64. A | |
| 25. D | 65. A | |
| 26. A | 66. D | |
| 27. E | 67. D | |
| 28. D | 68. A | |
| 29. D | 69. E | |
| 30. A | 70. C | |
| 31. B | 71. A | |
| 32. B | 72. C | |
| 33. A | 73. B | |
| 34. A | 74. A | |
| 35. E | 75. B | |
| 36. C | 76. D | |
| 37. D | 77. A | |
| 38. E | 78. D | |
| 39. C | 79. D | |
| 40. C | 80. D | |