



# The 58<sup>th</sup> Annual Merck State Science Day Competition May 20, 2008

## 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

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

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

$$C = 2f$$

$$h_i/h_o = d_i/d_o$$

$$E = hf$$

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

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

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

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

$$Q = mc\Delta T$$

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

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

$$W = F \times S$$

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

$$W = Vq$$

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

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

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

$$v_f = v_i + at$$

$$c = f\lambda$$

$$P_1 V_1 / T_1 = P_2 V_2 / T_2$$

$$I = V/R$$

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

$$D = M/V$$

$$v = f \lambda$$

$$P = W/t$$

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

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

(I) In dry milling, the entire corn kernel or other starchy grain is first ground into flour, which is referred to in the industry as "meal" and processed without separating out the various component parts of the grain. The meal is slurried with water to form a "mash." Enzymes and ammonia are added to the mash.

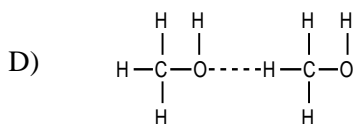
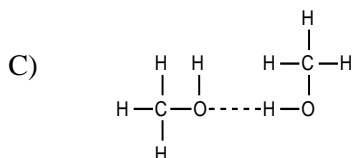
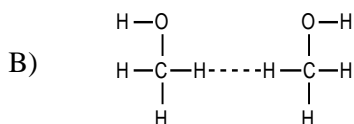
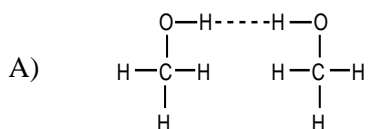
The mash is processed in a high-temperature cooker to reduce bacteria levels then the mash is cooled and yeast is added. The process generally takes about 40 to 50 hours. During this part of the process, the mash is agitated and kept cool to facilitate the activity of the yeast. Next, the resulting mixture is transferred to distillation columns where the ethanol is separated from the remaining "stillage." The ethanol is concentrated to 190 proof using conventional distillation and then is dehydrated to approximately 200 proof in a molecular sieve system.

The ethanol is then blended with about 5% denaturant (such as natural gasoline). It is then ready for shipment to gasoline terminals or retailers.

The stillage is sent through a centrifuge that separates the coarse grain from the solubles. The solubles are then concentrated to about 30% solids by evaporation, resulting in Condensed Distillers Solubles (CDS) or "syrup." The coarse grain and the syrup are then dried together to produce dried distillers grains with solubles (DDGS), a high quality, and nutritious livestock feed. (*Source: <http://www.ethanolrfa.org/resource/made>*)

- 1) What biological process is used to create ethanol?
  - A) photosynthesis
  - B) alcoholic fermentation
  - C) lactic acid fermentation
  - D) decomposition
  - E) dehydration
  
- 2) Which of the following are reasons for adding ammonia to the mixture?
  - I. increase the pH
  - II. decrease the pH
  - III. supply inorganic nutrients for the yeast
  - A) I only
  - B) II only
  - C) I and III only
  - D) II and III only
  - E) I, II, and III
  
- 3) Ethanol is used as a "biofuel" to replace fossil fuels. Proponents of ethanol use claim which of the following advantages of ethanol over fossil fuels?
  - I. Ethanol is a renewable resource; fossil fuels are nonrenewable.
  - II. Burning ethanol results in lower CO emissions than burning fossil fuels.
  - III. Ethanol is less toxic than fossil fuels.
  - IV. Ethanol use lowers greenhouse gas emissions.
  - V. Efficient processes for large-scale ethanol production are already in place.
  - A) only one of the above
  - B) only two of the above
  - C) only three of the above
  - D) only four of the above
  - E) all of the above.

- 4) Which of the following is **NOT** a possible negative environmental effect of replacing fossil fuels with ethanol?
- Ethanol production will require greater use of pesticides.
  - Ethanol production will compete with food production.
  - Ethanol production will require a large input of fossil fuel use.
  - Ethanol fuel will release more  $\text{CO}_2$  than fossil fuel.
  - Ethanol production will require large amounts of fresh water.
- 5) Which of the following is **NOT** a true advantage to using ethanol instead of gasoline in your automobile?
- Ethanol has more stored energy than gasoline.
  - Ethanol also acts as antifreeze.
  - Ethanol burns more cleanly.
  - Ethanol has a high octane rating.
  - Ethanol does not leave a residue in the engine.
- 6) Like ethanol, which of the following compounds is an alcohol?
- $\text{C}_3\text{H}_5(\text{OH})_3$
  - $\text{C}_2\text{H}_5\text{CHO}$
  - $\text{C}_2\text{H}_5\text{OC}_2\text{H}_5$
  - $\text{HCOOH}$
- 7) The ethanol molecule has a structure best described by the term
- cubic.
  - trigonal planar.
  - tetrahedral.
  - tetragonal.
- 8) Which best represents hydrogen bonding in liquid methanol ( $\text{CH}_3\text{OH}$ )?



9) Which compound would have the highest viscosity?

- A) n-propanol,  $C_3H_7OH$
- B) ethylene glycol,  $C_2H_4(OH)_2$
- C) propylene glycol,  $C_3H_6(OH)_2$
- D) glycerol,  $C_3H_5(OH)_3$

10) 800 g of ethanol ( $C_2H_5OH$ ) was added to 8000 g of water. How much would this lower the freezing point?

$$K_f \text{ for water} = 1.86 \text{ } ^\circ\text{C}\cdot m^{-1}$$

- A) 3.2  $^\circ\text{C}$
- B) 4.1  $^\circ\text{C}$
- C) 8.2  $^\circ\text{C}$
- D) 16  $^\circ\text{C}$

(II) Kwami and his family live in sub-saharan Africa. One day, Kwami fell ill with a fever. He took some aspirin for the fever, but this treatment caused him to become even weaker. Blood work showed that his red blood cell count had dropped dramatically. He was diagnosed with hemolytic anemia, a reaction to the aspirin caused by the fact that he had Glucose-6-Phosphate Dehydrogenase Deficiency (G6PD), an inherited disorder. The family was told that G6PD is sometimes called favism, because afflicted individuals also suffer from hemolytic anemia after eating fava beans.

Family history showed the Kwami had suffered a severe case of neonatal jaundice. His mother, Regina, was healthy but had suffered a mild case of malaria as a teenager. Regina's three sisters also had had mild malaria episodes. Regina and her sister Mary loved eating fava beans; however Mary's son Ernest would get extremely ill if he ever ate the beans. Regina's brother Aday had died after eating fava beans, but her brother Christian was healthy. Christian's six children were also healthy.

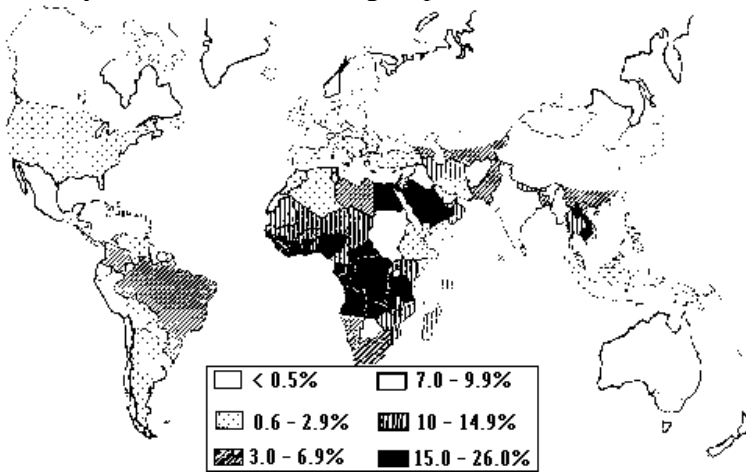
Kwami's father Ohene did not have favism. His five siblings were all healthy.

Kwami was treated with oxygen and a blood transfusion. After his release, he found the following information on emedicine.com:

*The G6PD enzyme catalyzes the oxidation of glucose-6-phosphate to 6-phosphogluconate while concomitantly reducing the oxidized form of nicotinamide adenine dinucleotide phosphate ( $NADP^+$ ) to nicotinamide adenine dinucleotide phosphate (NADPH). NADPH, a required cofactor in many biosynthetic reactions, maintains glutathione in its reduced form.*

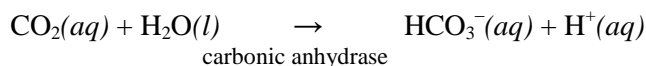
*Reduced glutathione acts as a scavenger for dangerous oxidative metabolites in the cell. With the help of the enzyme glutathione peroxidase, reduced glutathione also converts harmful hydrogen peroxide to water. Red blood cells rely heavily upon G6PD activity.*

Additionally, he found the following map of the worldwide distribution of G6PD.



- 11) This genetic disorder is extremely common. The disorder most likely persists because
- A) natural selection has not had enough time to eliminate the defective allele.
  - B) extensive inbreeding has increased the allele's frequency.
  - C) heterozygotes have an increased resistance to malaria.
  - D) the founder's effect has caused an unusually high allele frequency.
  - E) there is no selection pressure against the allele.
- 12) The most likely inheritance pattern for G6PD is
- A) simple dominant
  - B) simple recessive
  - C) sex-linked dominant
  - D) sex-linked recessive
  - E) incomplete dominant
- 13) Why are Kwami's red blood cells affected by this deficiency while other cells are not?
- A) Red blood cells lack mitochondria, unlike other cells.
  - B) Red blood cells are longer-lived than other cells.
  - C) Red blood cells are more active than other cells.
  - D) Red blood cells are more exposed to toxins than other cells.
  - E) Red blood cells have a more important digestive function than other cells.
- 14) Besides feeling weak after taking the aspirin, which other symptom did Kwami most likely display?
- A) increased fever
  - B) rigid muscle tone
  - C) increased appetite
  - D) trouble breathing
  - E) decreased urination
- 15) If Kwami marries a woman whose ancestors were from northern China, what is the probability that they will have a child with favism?
- A) 0%
  - B) 25%
  - C) 50%
  - D) 75%
  - E) 100%

- 16) The human body contains about 70% water by mass. A body temperature close to 37°C is vital to survival. The property of water that allows the body to maintain an almost-constant temperature despite sudden changes in ambient temperature is its high
- heat of fusion
  - heat of vaporization
  - specific heat capacity
  - enthalpy of formation
- 17) When 10.0 g of water evaporates with no change in temperature, the water will
- release approximately 22.6 kJ of energy
  - release approximately 40.8 kJ of energy
  - absorb approximately 22.6 kJ of energy
  - absorb approximately 40.8 kJ of energy
- 18) Which of the following can form hydrogen bonds in the pure liquid state?
- CH<sub>3</sub> - CH<sub>2</sub> - F
  - CH<sub>3</sub> - CH<sub>2</sub> - OH
  - CH<sub>3</sub> - N(CH<sub>3</sub>) - CH<sub>3</sub>
- 2 and 3
  - 3 only
  - 1 and 2
  - 2 only
- 19) There are a number of chemical systems within the body that are extremely dependent on pH, buffering action and concentration of dissolved gases like CO<sub>2</sub> and O<sub>2</sub>. The function of chemical buffers in the blood is to
- control all reactions
  - act as catalysts to increase the rate of reaction
  - withstand the continual addition of acid or base
  - maintain a constant pH when a small amount of acid or base is added
- 20) One of the buffers present in blood is
- HSO<sub>3</sub><sup>-</sup>(aq) – H<sub>2</sub>SO<sub>3</sub>(aq)
  - HCO<sub>3</sub><sup>-</sup>(aq) – H<sub>2</sub>CO<sub>3</sub>(aq)
  - NO<sub>3</sub><sup>-</sup>(aq) – HNO<sub>3</sub>(aq)
  - Cl<sup>-</sup>(aq) – HCl(aq)
- 21) Blood pH is influenced by the concentration of buffers and gas solutes, such as carbon dioxide, which is formed during cellular respiration. In red blood cells, the enzyme carbonic anhydrase catalyzes the equilibrium



In this equilibrium, carbonic anhydrase

- increases the concentration of HCO<sub>3</sub><sup>-</sup>(aq) formed at equilibrium
- decreases the concentration of HCO<sub>3</sub><sup>-</sup>(aq) formed at equilibrium
- decreases the concentration of CO<sub>2</sub>(g) at equilibrium
- increases the speed at which equilibrium is reached

22) Use the following information to answer this question.

pH of Blood Effect

7.50	alkalosis (life threatening)
↑	
7.35	<i>healthy individual</i>
↓	
7.20	acidosis (life threatening)

Which of the following substances can be added to the blood of a young child with kidney disease in order to control acidosis?

- A)  $\text{CO}_2(g)$
- B)  $\text{HCO}_3^-(aq)$
- C)  $\text{H}_2\text{O}(l)$
- D)  $\text{H}_2\text{CO}_3(aq)$

(III) Toy balloons will float in air when the balloon is filled with a lower density gas, such as helium. Hot-air balloons float in air when the air inside the balloon envelope is made less dense by heating the air inside the envelope. In the early 1960's hot air balloons became popular not as a means of transportation, but rather as a form of recreation. Balloon pilots are often asked, "How many passengers can fly in your balloon?" The answer depends on the weight of the passengers. **Gross lift** is the lift provided by the gas in a balloon. **Gross weight** is the total weight of the balloon envelope plus basket. **Free lift** is the weight a balloon system can lift off the ground. This is the maximum weight of the passengers and the balloon pilot.



Free lift is the difference between Gross lift and Gross weight.

When the Gross lift and Gross weight, plus passengers with pilot, are equal, the balloon will neither rise nor descend. The balloon is at "equilibrium." A skilled pilot can use the burner system to keep a hot-air balloon at equilibrium and have the basket skim over grass without touching the ground.

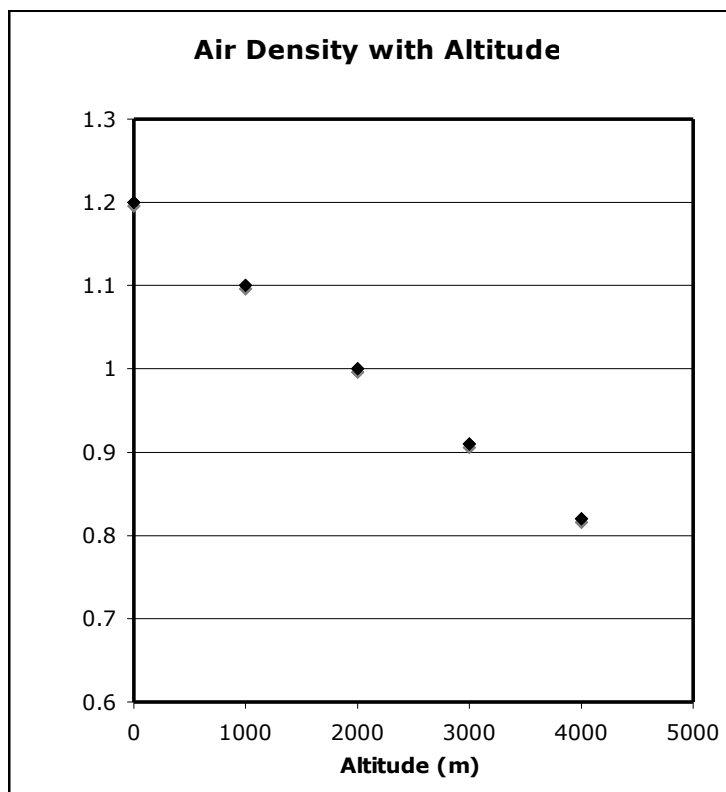
Gross lift is the difference between the weight of denser gas and the weight of the less dense gas

23) Using the following data, how many 150-pound people (including the pilot) can the hot air balloon carry?

Envelope (the balloon)	= 91 Kg
Basket, fuel, equipment	= 181 Kg
Envelope volume	= $2.18 \times 10^6\text{L}$
Air Temperature	= $21^\circ\text{C}$
Air Pressure	= 1.0 atm.
Molar mass of air	= 29.2 g/mol
Air heated by burner	= $110^\circ\text{C}$

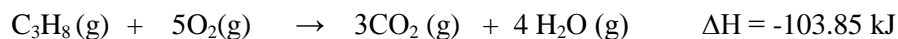
- A) two
- B) three
- C) four
- D) five

- 24) If the balloon above holds only the pilot, to what altitude would the balloon rise given the approximate data in the graph below?



Source: <http://www.2-stroke-porting.com/altiden.htm>

- A) 1000  
 B) 2000  
 C) 3000  
 D) 4000
- 25) The graph in #2 describes the approximate variation of density with altitude. What factors will play a significant role in determining the actual density of air at a given altitude?  
 (1) pressure      (2) temperature      (3) humidity
- A) 2 only  
 B) 1 & 2  
 C) 2 & 3  
 D) 1, 2 & 3
- 26) Modern hot air balloons heat the air in the envelope by burning propane gas,  $C_3H_8$ , stored in compressed liquid form. The lightweight cylinders are kept in the balloon basket. If the pilot burns 25% of a tank containing 20 lb. of propane, how much heat is released to the air?

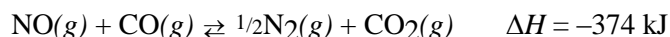


- A) -11.8 kJ  
 B) -5.20 kJ  
 C)  $-5.36 \times 10^3$  kJ  
 D)  $-2.14 \times 10^4$  kJ



- 27) A mixture of 11.0 g of CO<sub>2</sub> and 8.00 g of O<sub>2</sub> and an undetermined amount of H<sub>2</sub> occupies 22.4 L at 760 mmHg and 0.00 °C. How many grams of H<sub>2</sub> are present?
- A) 0.100 g
  - B) 0.500 g
  - C) 1.00 g
  - D) 2.00 g
- 28) One liter of helium, He, will diffuse through a certain nylon screen in 12 min. How long would it take for 1 L of heptane, C<sub>7</sub>H<sub>16</sub>, to diffuse through the same screen at the same temperature?
- A) 12 min
  - B) 25 min
  - C) 60 min
  - D) 100 min
- 29) A liter of carbon dioxide gas is compared to a liter of hydrogen gas, both gases at 25 °C and 2 atm. Which statement is correct?
- A) The CO<sub>2</sub> and H<sub>2</sub> molecules have the same average speed.
  - B) The average kinetic energy of the CO<sub>2</sub> molecules is greater than that of the H<sub>2</sub> molecules.
  - C) The CO<sub>2</sub> and H<sub>2</sub> molecules hit the walls of the containers with the same frequency.
  - D) The CO<sub>2</sub> molecules are on the average moving slower than the H<sub>2</sub> molecules.

30) Consider this reaction.



The conditions of temperature and pressure that favor the formation of CO<sub>2</sub> are

- A) high *T* and high *P*.
  - B) high *T* and low *P*.
  - C) low *T* and high *P*.
  - D) low *T* and low *P*.
- 31) The equilibrium constant for the reaction



is 10 at a certain temperature, when concentrations are expressed in moles per liter. Calculate the number of moles of HBr(*g*), present at equilibrium if 100 L of the equilibrium mixture contain 5 mol of H<sub>2</sub>(*g*) and 8 mol of Br<sub>2</sub>(*g*).

- A) 0.25
- B) 0.5
- C) 1
- D) 2
- E) 4

- 32) A balloon is 20.0 meters off the ground travelling upward at 20.0 m/s. A small object is released from rest, relative to the balloon and travels straight downward, hitting the ground. (no friction with the air) It required approximately \_\_\_ seconds for the object to reach the ground.
- A) 2  
B) 3  
C) 4.4  
D) 5  
E) 6
- 33) At the same point in time when the object was released, a second identical object was projected straight upward from a location below the balloon. Its launch speed relative to the ground was 20.0 m/s. The objects pass each other approximately \_\_\_ m off the ground.
- A) 40  
B) 35  
C) 30  
D) 25  
E) never pass each other.
- 34) If two objects were released from a stationary balloon 20.0 m off the ground, one released 1.5 seconds after the other; they will strike the ground \_\_\_ s apart.
- A) 2.1  
B) 1.8  
C) 1.5  
D) 1.2  
E) 0.9

(IV) The following data come from a Florida aquatic ecosystem. The sun delivers 1,734,167 kcal/m<sup>2</sup>/year to this ecosystem.

organisms	gross productivity (kcal/m <sup>2</sup> /year)	net productivity (kcal/m <sup>2</sup> /year)
aquatic plants	20,810	7,631
herbivores: snails, shrimp, insects, small fish, turtles	3,368	1103
carnivorous invertebrates and fish	383	111
large fish	21	5

- 35) Which of the following account(s) for the differences between gross and net productivity?
- I. experimental error  
II. metabolism  
III. photosynthesis  
IV. respiration  
V. unconsumed organisms
- A) only one of the above  
B) only two of the above  
C) only three of the above  
D) only four of the above  
E) all of the above

- 36) Global warming may cause an increase in cloud cover. If the amount of sunlight reaching this ecosystem were decreased by 10%, which of the following is most likely to occur?
- A) Water's high specific heat would compensate for the energy change.
  - B) Primary productivity would slightly decrease without affecting the other trophic levels.
  - C) A 10% decrease in productivity would occur in all trophic levels.
  - D) A decrease in decomposition would compensate for the decrease in sunlight.
  - E) The top carnivores would become endangered.
- 37) Why aren't there any quaternary consumers in this ecosystem?
- A) The large fish are too strong to be preyed upon by other animals.
  - B) There is too little energy to support another population.
  - C) Hunting and habitat destruction have caused those consumers to become extinct.
  - D) Fish are better adapted to be herbivores than to be carnivores.
  - E) Inadequate field sampling techniques caused inaccurate population counts.
- 38) Which of the following ecosystem components is missing from this diagram?
- A) decomposers
  - B) humans
  - C) predators
  - D) land plants
  - E) energy recycling
- 39) If a similar study was performed in a mid-latitude deciduous forest
- A) the pattern of measurements and number of trophic levels would be very similar to the Florida system.
  - B) the forest would have more trophic levels and a more complex food web than the Florida system.
  - C) in the forest, at least 20% of the energy of each trophic level would be passed to the next level.
  - D) the forest would have lower primary productivity and fewer trophic levels.
  - E) the forest would have greater loss to respiration at each trophic level than the Florida system.
- 40) Radiant energy from the Sun is stored by plants. This energy is released when plant material undergoes
- A) a phase change
  - B) a nuclear change
  - C) a chemical change
  - D) a formation reaction
- 41) The molar heat of solution for  $\text{NaOH}(s)$  is  $-44.6 \text{ kJ/mol}$ . If  $25.0 \text{ g}$  of  $\text{NaOH}(s)$  is dissolved in water in a calorimeter, the heat released inside the calorimeter is
- A)  $27.9 \text{ kJ}$
  - B)  $71.4 \text{ kJ}$
  - C)  $1.12 \text{ MJ}$
  - D)  $1.78 \text{ MJ}$
- 42) A  $10.0 \text{ g}$  sample of silver is heated to  $100.0 \text{ }^\circ\text{C}$  and then added to  $20.0 \text{ g}$  of water at  $23.0 \text{ }^\circ\text{C}$  in an insulated calorimeter. At thermal equilibrium the temperature of the system was measured as  $25.0 \text{ }^\circ\text{C}$ . What is the specific heat of silver?
- A)  $0.11 \text{ J/g}\cdot^\circ\text{C}$
  - B)  $0.22 \text{ J/g}\cdot^\circ\text{C}$
  - C)  $17 \text{ J/g}\cdot^\circ\text{C}$
  - D)  $34 \text{ J/g}\cdot^\circ\text{C}$

(V) Urban plants frequently suffer from chlorosis, loss of green color, caused by ozone damage. Plants protect themselves from high ozone concentrations by closing their stomata. The genetic basis of this action was recently found by researchers in Finland through the isolation of an *Arabidopsis* mutant which was extremely sensitive to ozone. This mutant does not close its pores in the presence of high ozone levels. Researchers discovered that the biological basis of the mutation a defect in a slow or S-type anion channel which regulates the closing of stomatal pores. Therefore, the newly discovered gene is called SLAC1 for “slow anion channel 1”.

- 43) When exposed to high concentrations of ozone for long periods of time, plants with the normal functioning SLAC1 gene would
- A) lose their green color, thus displaying chlorosis.
  - B) open their stomata to obtain more O<sub>2</sub> for energy reactions.
  - C) close their stomata and have a slower growth rate.
  - D) mutate to the non-functioning SLAC1 gene for protection.
  - E) revert to the C4 pathway for photosynthesis.
- 44) This gene discovery has significance for the environmental problem of
- A) global warming because plants exposed to high ozone will take in less CO<sub>2</sub>.
  - B) the ozone hole because mutant plants will take in more ozone.
  - C) acid deposition because the SLAC1 gene depends on anions to function properly.
  - D) increasing desertification because mutant plants have an increased stress response.
  - E) preservation of endangered species because gene therapies can be developed to correct the mutant gene.
- 45) Plants are exposed to high concentrations of ozone due to
- A) continued use of CFC's and halons in developing countries.
  - B) the disruptive effects of global warming and climate change.
  - C) problems of a shrinking freshwater supply and increased desertification.
  - D) increasing number of vehicles emitting NO<sub>x</sub> and hydrocarbons into the air.
  - E) increased burning of coal in factories in Asia and South America.
- 46) The SLAC1 gene is most likely to be highly active in \_\_\_\_\_ cells
- A) epidermal
  - B) mesophyll
  - C) stomatal
  - D) guard
  - E) cuticle
- 47) A greater understanding of this gene might allow scientists to breed plants which are
- A) herbicide resistant
  - B) faster growing
  - C) drought resistant
  - D) more nutritious
  - E) radiation resistant
- 48) In the ozone molecule, O<sub>3</sub>, the electrons are distributed as
- A) 6 lone pairs, 3 bond pairs
  - B) 7 lone pairs, 2 bond pairs
  - C) 6 lone pairs, 2 bond pairs
  - D) 7 lone pairs, 3 bond pairs
  - E) 5 lone pairs, 4 bond pairs

49) Chlorofluorocarbons were widely used as refrigerants until it was discovered that they were destroying the ozone layer. One of these, Freon-12, undergoes a series of reactions as shown below (not in sequence). Which of these is the chain initiation reaction?

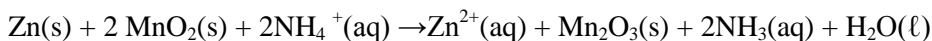
- A)  $O\cdot + O_3 \rightarrow 2O_2$
- B)  $CF_2Cl_2 \rightarrow \cdot CF_2Cl + Cl\cdot$
- C)  $Cl\cdot + O_3 \rightarrow ClO\cdot + O_2$
- D)  $\cdot CF_2Cl + \cdot CF_2Cl \rightarrow C_2F_4Cl_2$

50) Which chemical species have a +6 oxidation number for Cr?

- I.  $Cr_2O_7^{2-}$
- II.  $CrO_4^{2-}$
- III.  $Cr(OH)_3$

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

51) Which species is the reducing agent in the reaction below?



- A) Zn
- B)  $Zn^{2+}$
- C) N in  $NH_4^+$
- D) Mn in  $MnO_2$
- E) Mn in  $Mn_2O_3$

(VI) The production of petroleum in the US peaked in 1971. Natural gas production from traditional US basins appears to have reached a plateau. Among the alternatives to the use of fossil fuels is solar power. A person uses about  $10^{21}$  Joules of energy a year; that much energy reaches the earth from the sun in an hour or two. Fossil fuels are compact, but expensive.

52) Which of the following features of the use of solar power is not true? Energy through the use of sun light \_\_\_\_.

- A) has wide availability
- B) is in large supply
- C) is non-renewable
- D) in some uses, can be locally non-polluting
- E) will require extensive storage in order to be widely used

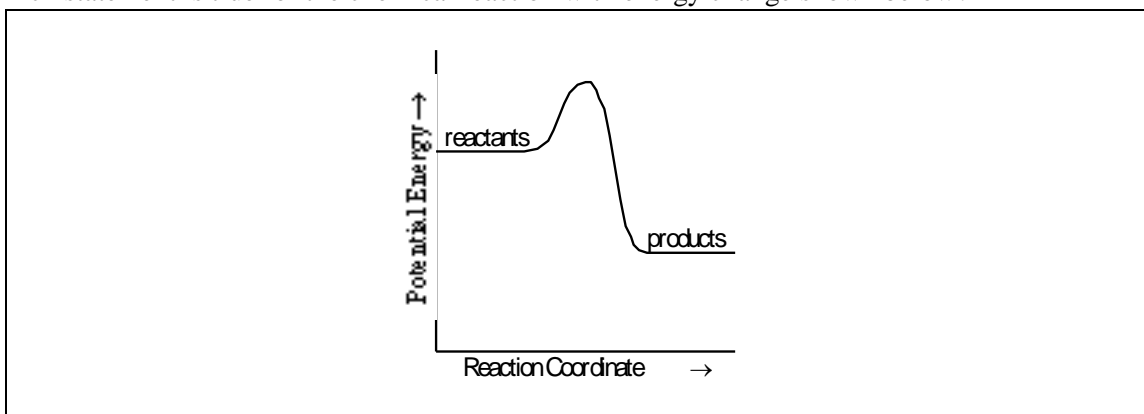
53) Sunlight can be converted into \_\_\_\_.

- I. electrical energy
- II. chemical energy
- III. fuel

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

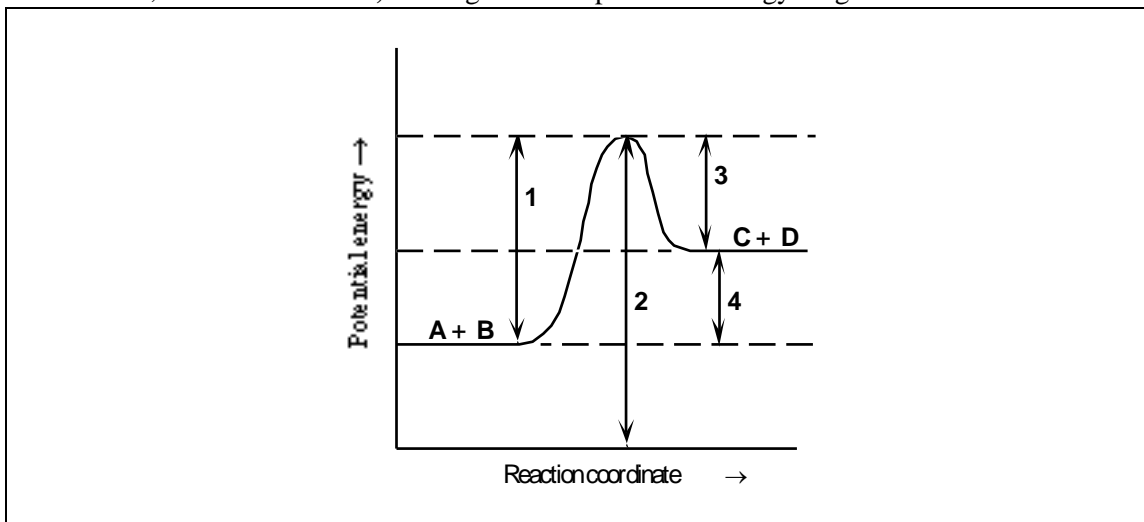
- 54) Of the following which is the least efficient conversion process for converting sunlight to energy?
- photosynthesis by conventional crops
  - photovoltaic cell
  - generating plant where steam produced by solar power runs generators
  - solar power towers
  - solar water heaters mounted on a roof
- 55) In our latitude a feature of a solar heated home would not be \_\_\_\_.
- house faces south
  - home would have a few inch thick walls
  - clerestory to get sunlight to the rear of rooms
  - masonry wall or floor or stationary water
  - a large amount of glass (windows) on one side

- 56) Which statement is true for the chemical reaction with energy change shown below?



- The reaction is exothermic.
- The reaction is endothermic.
- The reaction requires a catalyst.
- The energy of the products is greater than the energy.

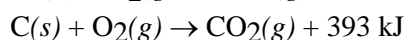
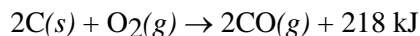
- 57) For the reaction,  $A + B \rightarrow C + D$ , this figure is the potential–energy diagram



What interval represents the net energy change for this reaction?

- 1
- 2
- 3
- 4

58) Given:



How much energy is produced in the combustion of 28 g of CO?

- A) 88 kJ
- B) 109 kJ
- C) 175 kJ
- D) 284 kJ

59) Vaporization of a liquid is an example of a process for which

- A)  $\Delta H$ ,  $\Delta S$ , and  $\Delta G$  are positive at all temperatures.
- B)  $\Delta H$  and  $\Delta S$  are positive.
- C)  $\Delta G$  is negative at low temperatures, positive at high temperatures.
- D)  $\Delta H = \Delta S$

60) Nuclear energy produces about 8 percent of the U.S. energy production. The process involved is nuclear fission in which a reduction in mass results in the production of energy. A neutron which bounces off a uranium nucleus loses \_\_\_\_ momentum than the same neutron bouncing off a hydrogen nucleus, both collisions being head-on.

- A) more
- B) the same amount (but moves forward)
- C) the same amount (but moves backward)
- D) less

61) If a uranium nucleus fissions, that is, splits into parts, the mass of the uranium nucleus before fission was \_\_\_\_ the total mass of the parts formed in the fission. Consider the uranium nucleus to be at rest.

- A) more than
- B) the same as
- C) less than

(VII) A young boy had experienced several instances of temporary paralysis of his legs when he rested after he had been playing outside. Each time, he recovered after several minutes. He was diagnosed with a genetic defect called hyperkalemic periodic paralysis. In this condition, the  $\text{Na}^+$  channels in skeletal muscle fibers remain open for abnormally long periods of time.  $\text{K}^+$  also accumulates in the muscle fibers. The boy's father, father's sister, and father's mother had also experienced similar episodes during their lives. Other family members were not known to be affected.

62) What happened to the membrane potential of the boy's skeletal muscles during these paralysis episodes?

- A) The influx of  $\text{Na}^+$  caused the membrane to depolarize.
- B) The influx of  $\text{Na}^+$  caused the membrane to hyperpolarize.
- C) The efflux of  $\text{Na}^+$  caused the membrane to depolarize.
- D) The efflux of  $\text{Na}^+$  caused the membrane to hyperpolarize.
- E) The accumulation of  $\text{K}^+$  balanced out the loss of  $\text{Na}^+$ .

63) Why does this defect cause paralysis?

- A) The muscle fiber cannot repolarize or fire additional action potentials.
- B) The muscle fiber cannot repolarize or receive additional action potentials.
- C) The muscle fiber is hyperpolarized and continuously firing action potentials.
- D) The muscle fiber is hyperpolarized and cannot receive additional action potentials.
- E) The muscle fiber is neutralized and cannot fire action potentials.

- 64) How do the boy's muscles feel during a paralytic episode?
- stiff and tight
  - relaxed and flexible
  - hot and tender
  - cold and twitching
  - rapidly contracting and relaxing
- 65) One treatment for the paralytic episodes is to provide glucose orally. Why might this help?
- Foods with glucose often have added salt. The salt will help restore the Na balance.
  - Sweet foods have a comforting effect, which will cause the muscles to relax.
  - Glucose restores the osmotic gradient between blood and muscle cells.
  - Sugar pills have a placebo effect and are useful in many neurological conditions.
  - Glucose will help the muscles produce more ATP for use in active transport.
- 66) The inheritance pattern for this condition is most likely
- sex-linked recessive
  - sex-linked dominant
  - autosomal recessive
  - autosomal dominant
  - Y-linked
- 67) Which of the following treatments might also be helpful?
- insulin
  - potassium
  - sodium
  - aspirin
  - thyroxin
- 68) The radioactive isotope Na-24 is used to observe the circulation of blood. What isotope is produced when Na-24 decays by emitting a beta particle, which is a fast-moving electron?
- Mg-24
  - Na-25
  - Ne-23
  - Na-23
  - Mg-25
- 69) Half-life is the amount of time required for a sample of a radioactive nuclide to decay to one half its value. If this rule applied to people and the half-life for people "born and raised" in the United States was 60 years, and the starting sample was 200,000,000 of these people, in 100 years the remaining sample would contain \_\_\_ million people.
- 120
  - 100
  - 86
  - 63
  - 50
- 70) The ionic radii of some ions are:  $\text{Na}^+$ , 0.095 nm;  $\text{Mg}^{2+}$ , 0.065 nm;  $\text{F}^-$ , 0.136 nm;  $\text{I}^-$ , 0.216 nm;  $\text{O}^{2-}$ , 0.140 nm;  $\text{S}^{2-}$ , 0.184 nm. Consider the following compounds and arrange them in order of decreasing lattice energy.
- NaF NaI MgO MgS**
- $\text{NaF} > \text{NaI} > \text{MgS} > \text{MgO}$
  - $\text{MgS} > \text{MgO} > \text{NaI} > \text{NaF}$
  - $\text{NaI} > \text{NaF} > \text{MgO} > \text{MgS}$
  - $\text{NaF} > \text{NaI} > \text{MgO} > \text{MgS}$
  - $\text{MgO} > \text{MgS} > \text{NaF} > \text{NaI}$



71) Which of the following is a nonpolar molecule?

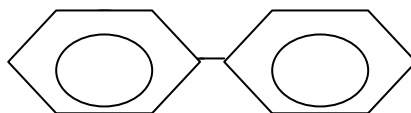
- A)  $\text{BCl}_3$
- B)  $\text{H}_2\text{O}$
- C)  $\text{PCl}_3$
- D)  $\text{CH}_2\text{Cl}_2$
- E)  $\text{NO}$

72) Given a nucleus of nitrogen. The atomic number (number of protons) of nitrogen is 7. This particular nucleus has 13 nucleons. It decays by emitting a positron. The number of protons in the nucleus to which it decays is \_\_\_\_.

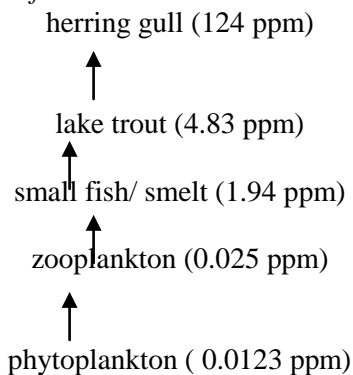
- A) 9
- B) 8
- C) 7
- D) 6
- E) 5

(VIII) PCB's, or polychlorinated biphenols, are a group of synthetic chemicals which were widely used from 1929 – 1979 in electrical transformers, dielectric fluids, and insulators. In many places, the use of these chemicals was required by fire codes, due to their many desirable properties such as non-flammability, stability, high boiling point and high flash point. However, the manufacture of PCB's was prohibited in the USA after 1979 when PCB's were linked to the decline of the brown pelican and osprey populations. More recently, PCBs have been linked to cancer, endocrine, nervous, and neurological problems. Refer to the information below as you answer the following questions.

*Basic PCB Shape; Chlorines can be substituted for any of the hydrogens.*



*PCB concentration in typical Lake Ontario food chain*



73) Based on the above information, PCBs should be

- A) highly soluble in water
- B) highly insoluble in water
- C) acidic
- D) basic
- E) crystalline

74) PCB concentration in organisms in Lake Ontario

- A) increases as trophic level increases.
- B) increases as population size increases.
- C) decreases as trophic level increases.
- D) decreases as population size increases.
- E) none of the above

- 75) Based on its chemical properties, high concentrations of PCBs should be found in
- blood.
  - muscle.
  - fatty tissue.
  - skin.
  - bones.
- 76) The organisms in Lake Ontario most likely to be harmed by PCBs are
- phytoplankton.
  - zooplankton.
  - smelt.
  - lake trout.
  - herring gulls.
- 77) Smelt have a greater PCB concentration than phytoplankton because
- smelt are larger than phytoplankton.*
  - smelt eat many phytoplankton.*
  - smelt live longer than phytoplankton.*
  - smelt are attracted to foods containing PCBs.*
- none of the above
  - one only of the above
  - two only of the above
  - three only of the above.
  - all of the above
- 78) Why are PCBs still an environmental problem if they were banned 30 years ago?
- illegal manufacture of PCBs
  - spontaneous formation of PCBs
  - stability of PCB compounds
  - long lives of lake organisms
  - water solubility of PCB
- 79) A cellophane bag, which acts as a membrane permeable only to water, contains a 2 M sugar solution. The bag is immersed in a 1 M sugar solution. What will happen?
- The bag will soon contain more solution that will be more concentrated than 2M.
  - The bag will soon contain more solution that will be less concentrated than 2 M.
  - The bag will lose sugar and the solution in it will become less concentrated.
  - The bag will lose water and the solution in it will become more concentrated.
  - There will be no change.
- 80) The solubility of a substance is 60 g per 100 mL water at 15 °C. A solution of the same substance is prepared by dissolving 75 g per 100 mL water at 75 °C and then is cooled slowly to 15 °C without any solid separating. The solution is
- supersaturated at 75 °C.
  - supersaturated at 15 °C.
  - unsaturated at 15 °C.
  - saturated at 15 °C.
- 81) What is the molarity of a solution 15.0 mL of which contains 89.3 mg KBr?
- 0.0500 M
  - 0.0900 M
  - 0.170 M
  - 19.0 M

(IX) A railroad transportation company hired a cleaning crew to steam clean the inside walls of a railroad tank car. The crew was properly suited with self-contained breathing suits and trained to use high pressure steam systems. The 100 000 L tank car is 55 ft. long and 8.5 ft. in diameter. It is made of 7/16<sup>th</sup> inch steel and has no negative pressure release valve. After the steam cleaning was completed, the outlet valves were shut and the tank sealed. When the workers returned the next morning, they saw the tank car had collapsed, looking like a crushed can. Assume STANDARD Atmospheric Pressure.

(Source: <http://gizmodo.com/383045/how-to-implode-a-tanker-car-in-under-a-second>)

Molar heat of vaporization<sub>H<sub>2</sub>O</sub> = 40.6 kJ

Molar heat of fusion<sub>H<sub>2</sub>O</sub> = 6.02 kJ

Specific heat<sub>H<sub>2</sub>O</sub> = 4.18 J/g·°C

Density<sub>steam</sub> = 0.6 g/L

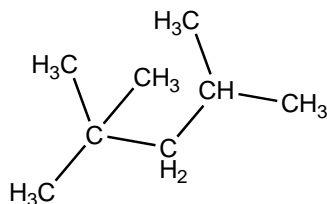
82) If 80% of the air in the tank was displaced by the steam, approximately what volume of liquid water was left in the tank after it was sealed? (Assume all the steam condenses)

- A) 50 L
- B) 60 L
- C) 70 L
- D) 80 L

83) How much heat energy, in kJ, is evolved when 150 L steam is condensed and cooled to 10°C?

- A) 237 kJ
- B) 256 kJ
- C) 3.38 x 10<sup>5</sup> kJ
- D) 6.49 x 10<sup>5</sup> kJ

84) Tank cars are used to transport hydrocarbon compounds such as isooctane produced in the petroleum industry as a component of gasoline. The structural formula of isooctane is:



The correct IUPAC nomenclature for this compound is

- A) 2,3,4 trimethylpentane
- B) 2,2,4, trimethylpentane
- C) 2,4 dimethylhexane
- D) 2 ethyl, 3 methylhexane

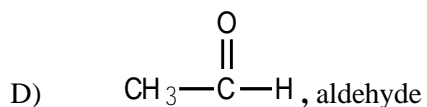
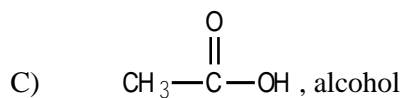
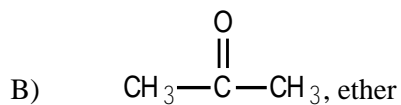
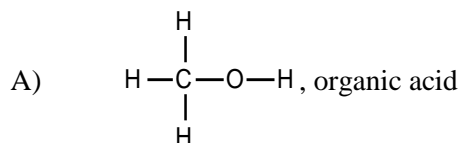
85) Isooctane differs from octane in that the former

- A) has a higher molecular weight.
- B) is not a saturated hydrocarbon.
- C) has a different empirical formula.
- D) has a different structural formula.

86) In the production of isooctane, an intermediate compound of isooctene is formed. The number of *pi* bonds in isooctene would be:

- A) one
- B) two
- C) three
- D) none

- 87) Which has the highest boiling point?  
A) 2-methylheptane  
B) 3,4-dimethylhexane  
C) *n*-hexane  
D) 2,2,4-trimethylpentane
- 88) Which straight-chain hydrocarbon is unsaturated?  
A) C<sub>3</sub>H<sub>8</sub>  
B) C<sub>5</sub>H<sub>10</sub>  
C) C<sub>6</sub>H<sub>14</sub>  
D) C<sub>7</sub>H<sub>16</sub>
- 89) The reaction of an alcohol with a carboxylic acid in organic chemistry resembles the reaction of an inorganic hydroxide with an acid only in  
A) the speed of the reaction.  
B) the completeness of the reaction.  
C) the production of an ionic salt as one end product.  
D) the production of water as one end product.
- 90) Isooctane is in a group of compounds called alkanes. Which of the following structures is correctly matched with its functional group?



The End