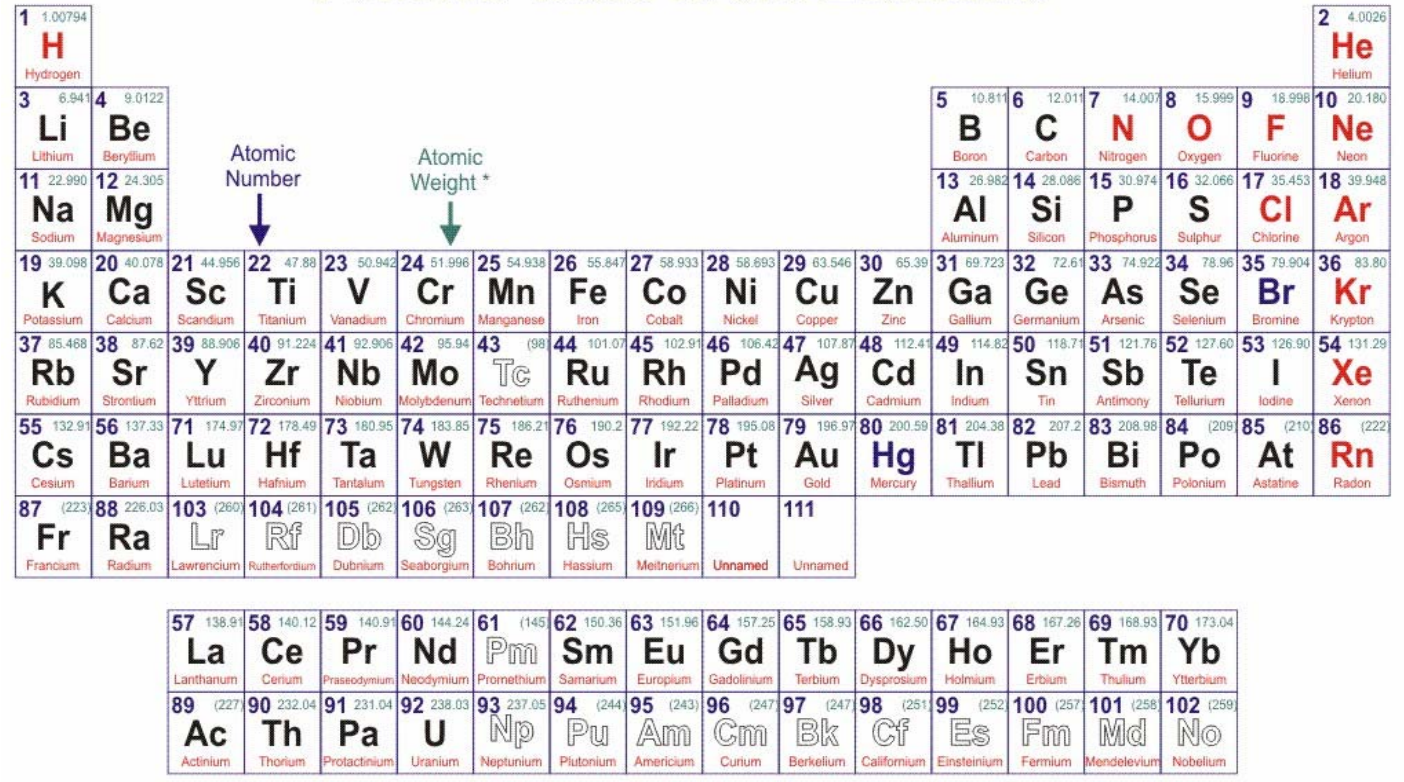
Chemistry (Environmental Studies) L111
Environmental Concerns and Chemical Solutions
Professor Dransfield
Final Exam
May 25, 2007

Name_____

Student ID Number _____

Periodic Table of the Elements



$N_A = 6.02 \times 10^{23}$ 1m = 10^9 nm 1 J = 1 kg·m^2/s^2

1 ppm = 1 mg/L 1 ppb = 1 μg/L $c = 3.00 \times 10^8$ m/s

$c = \lambda\nu$ $E=h\nu$ $h=6.63 \times 10^{-34}$ J·s

<u>63</u> multiple choice questions worth a total of <u>200</u> points, and 3 bonus problems worth a total of 15

Table 5.4 Electronegativity Values, Arranged by Group Number

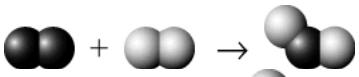
1A	2A	3A	4A	5A	6A	7A	8A
H							He
2.1							—
Li	Be	B	C	N	O	F	Ne
1.0	1.5	2.0	2.5	3.0	3.5	4.0	—
Na	Mg	Al	Si	P	S	Cl	Ar
0.9	1.2	1.5	1.8	2.1	2.5	3.0	—

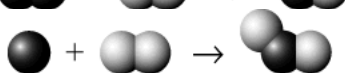
Table 4.2 Bond Energies (in kJ/mol)

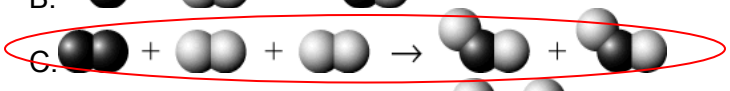
	H	C	N	O	S	F	Cl	Br	I
Single bonds									
H	436								
C	416	356							
N	391	285	160						
O	467	336	201	146					
S	347	272	—	—	226				
F	566	485	272	190	326	158			
Cl	431	327	193	205	255	255	242		
Br	366	285	—	234	213	—	217	193	
I	299	213	—	201	—	—	209	180	151
Multiple bonds									
C=C	598			C=N	616		C=O	803 in CO_2	
C≡C	813			C≡N	866		C≡O	1073	
N=N	418			O=O	498				
N≡N	946								

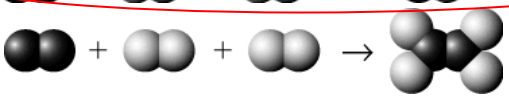
Source: Data from Darrell D. Ebbing, *General Chemistry,* Fourth Edition, 1993 Houghton Mifflin Co. Data originally from *Inorganic Chemistry: Principles of Structure and Reactivity,* Third Edition by James E. Huheey, 1983, Addison Wesley Longman.

1. Which shows the balanced equation for nitrogen ( ) reacts with oxygen ( ) to form nitrogen dioxide?

A. 

B. 

C. 

D. 

2. What is the primary component of an exhaled breath?
   - A. N_2
   - B. O_2
   - C. CO_2
   - D. H_2O

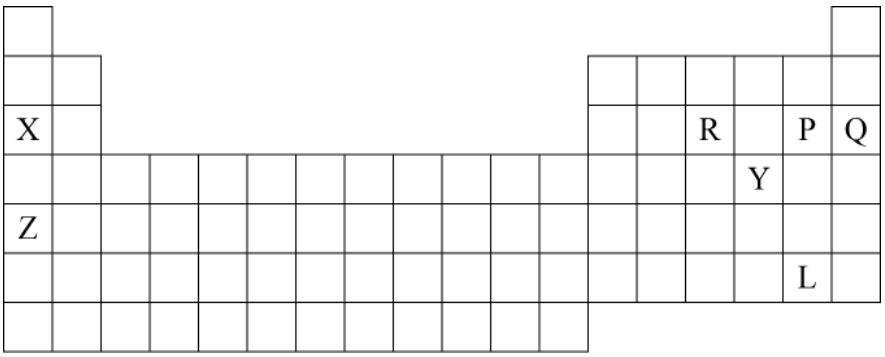
3. The EPA limit for CO is 9 ppm. Express this number as a percentage.
   - A. 90%
   - B. 9%
   - C. 0.09%
   - D. 0.0009%

4. The quantity 8.7×10^5 g expressed in standard decimal notation is:
   - A. 0.000087 g
   - B. 870.000 g
   - C. 0.0000087 g
   - D. 870,000 g

5. What level of the atmosphere occurs at the highest altitude?
   - A. ozone
   - B. stratosphere
   - C. mesosphere
   - D. troposphere

6. Which is ***not*** a pure substance?
   - A. helium
   - B. copper wire
   - C. air
   - D. sucrose

7. If representative element “X” reacts with representative element “P” the resulting formula would be:

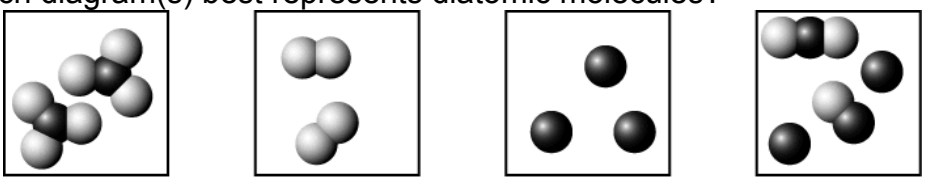


A. XP
B. XP_2
C. X_2P
D. X_2P_2

8. Choose the proper coefficients for each substance to yield a balanced equation.

A. 1, 1, 1
B. 2, 1, 1
C. 2, 1, 2
D. 2, 1, 1

9. Which diagram(s) best represents diatomic molecules?



A. **I** only
B. **II** only
C. **I** and **II** only
D. **II** and **IV** only

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10. O_2 and O_3 molecules are
A. allotropes.
B. structural isomers.
C. isotopes.
D. geometrical isomers.

11. What is one of the Lewis dot structures for ozone?

A. 

B. 

C. 

D. 

12. The production of which of the following classes of compounds was NOT limited by the Montreal Protocol of 1987 nor by its amendments:

A. CFCs
B. HCFCs
C. VOCs
D. Halons

13. Results of the Montreal protocol include

A. greatly reduced production of CFCs.
B. increased production of alternatives to CFCs.
C. recycling of CFCs.
D. All of the choices are correct.

14. The chemical properties of the elements are chiefly due to

A. the number of protons.
B. the number and distribution of the outer electrons.
C. the number and distribution of the inner electrons.
D. the number and distribution of the neutrons.

15. Chlorofluorocarbons rise to the stratosphere and

A. react directly with stratospheric ozone to destroy it.
B. after interacting with UV energy, become free radicals, which destroy ozone.
C. become free radicals that react with oxygen to create ozone.
D. react with free radicals to remove carbon dioxide.

16. The atomic number is the

A. same as the mass number of an atom.
B. number of protons in a nucleus.
C. number of protons and neutrons in the nucleus.
D. number of neutrons in a nucleus.

17. During the Antarctic spring, ozone is destroyed at a greater rate than it is formed

A. on the surface of atmospheric ice crystals.
B. in a process that is catalytic.
C. in polar stratospheric clouds.
D. All of the choices are correct.

18. Increasing energy of light goes in the order
A. ultraviolet, visible, infrared.
B. visible, infrared, ultraviolet.
C. infrared, visible, ultraviolet.
D. ultraviolet, infrared, visible.

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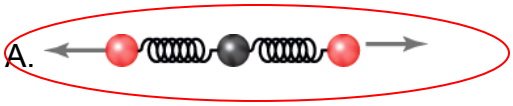
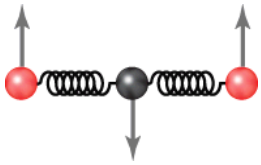
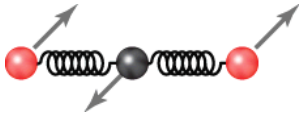
19. Scientists believe they know the average global temperature over the last 160,000 years. Which property of the ice core samples from Antarctica provides this information?
A. their thickness
B. their carbon dioxide concentration
C. their $^{1}H/^{2}H$ ratio
D. their temperature

20. Which vibrational mode for carbon dioxide is not expected to contribute to the greenhouse effect?

A. 

B. 

C. 

D. 

21. Predict the geometry of nitrous oxide, N_2O (atomic order N–N–O).
A. linear
B. bent
C. trigonal pyramidal
D. trigonal planar

22. The Intergovernmental Panel on Climate Change (IPCC) issued a report in 2001 which attached probabilities to the predictions and statements made. Which prediction/statement was considered "Very Unlikely"?
A. The temperatures in the northern hemisphere during the 20th century have been the highest for the past 1,000 years.
B. The observed warming over the past 100 years is due solely to climatic variability.
C. Carbon dioxide contributes to higher global temperatures.
D. Increased carbon dioxide levels are a consequence of human activity.

23. Hydrogen gas (H_2) is a promising alternative fuel because it does not produce greenhouse gases. How many molecules are present in 1.0 kg of hydrogen gas?

A. 3.0×10^{23}
B. 6.0×10^{23}
C. 3.0×10^{26}
D. 6.0×10^{26}

24. Determine the molar mass for fluoxetine ($C_{16}H_{16}F_3NO$), also known as Prozac®.

A. 279.3 g/mol
B. 281.3 g/mol
C. 295.3 g/mol
D. 297.1 g/mol

25. Both the Clinton and Bush (the younger) administrations have been unwilling to sign the Kyoto Protocol. What has been their primary objection to the treaty?

A. The target emission levels are not sufficiently low to affect the greenhouse effect.
B. The treaty does not include a provision for trading emission allowances.
C. Developing countries are not required to control greenhouse gas emissions.
D. Enforcement of the treaty will be impossible.

26. Which substances are regulated by the Kyoto Protocol?

I. argon
II. carbon dioxide
III. nitrogen
IV. nitrous oxide
V. sulfur hexafluoride

A. I, II and III only
B. I and III only
C. II and V only
D. II, IV and V only

27.Argon, which comprises almost 1% of the atmosphere, is approximately 27 times more abundant than CO_2, but doesn't contribute to global warming. Which explanation accounts for this fact?

A. Single atoms do not vibrate.
B. Argon's vibrational energy is not excited by infrared radiation.
C. The mass of argon does not allow it to reach sufficiently high in the atmosphere to interact with the earth's radiant energy.
D. Argon is transparent to UV radiation.

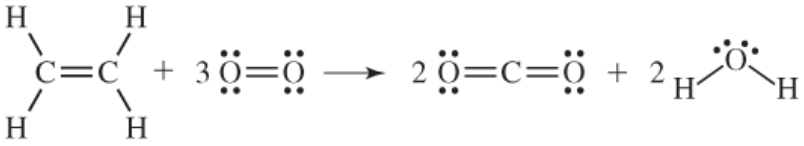
28. The conclusion that it is impossible to ***completely*** convert heat into work without making other changes in the universe is

A. based on erroneous observations.
B. the concept that increasing entropy characterizes all changes in the universe.
C. another way of stating that all energy is either thermal energy or heat.
D. the second law of thermodynamics.

29. The heat of combustion of ethane, C_2H_6, is 1560 kJ/mol. What is the heat of combustion of ethane, in kJ per gram?

A. 9.39×10^{26} kJ/g
B. 2.59×10^{-21} kJ/g
C. 51.9 kJ/g
D. 195 kJ/g

30.



Based upon the data in the Table of Bond Energies and the Lewis structures of reactants and products given above, what is the heat of combustion of ethylene, C_2H_4?

A. +220 kJ/mol
B. +1216 kJ/mol
C. –754 kJ/mol
D. –1324 kJ/mol

31. The combustion process for an effective fossil fuel must have an activation energy that is neither too high nor too low. Why is it problematic if the combustion has a very low activation energy?

A. The fuel will evaporate too easily and be hard to transport and store.
B. The fuel will ignite too easily and be hazardous.
C. Upon combustion, fuels with low activation energies produce greenhouse gases.
D. Upon combustion, fuels with low activation energies will not release useful amounts of energy.

32. A gasoline's octane rating is

A. a measure of the gasoline's resistance to causing knocking in a vehicle's engine.
B. a measure of the pollutants produced by burning the gasoline in a vehicle's engine.
C. a measure of the energy content of the gasoline; the higher the rating, the better the gas mileage.
D. a measure of the purity of the gasoline; the higher the rating the smaller the number of components in the mixture.

33. In an exothermic chemical reaction
A. the mass of the products is greater than the mass of the reactants.
B. the mass of the products is less than the mass of the reactants.
C. heat is released as the reaction proceeds.
D. heat is absorbed as the reaction proceeds.

34. The first law of thermodynamics states that
A. energy is the capacity to do work.
B. doing work is defined as causing movement against a resisting force.
C. heat flows from a warmer body to a cooler body.
D. energy is neither created nor destroyed.

35. Petroleum (crude oil) is a complex mixture of thousands of substances, the majority of which are
A. hydrocarbons.
B. natural gases.
C. complex carbohydrates.
D. cellulose-based substances.

36. In general, which does ***not*** increase the speed of a combustion reaction?
A. adding a catalyst
B. increasing the temperature of the reaction
C. increasing the amount of fuel present
D. using a combustion reaction with a high activation energy

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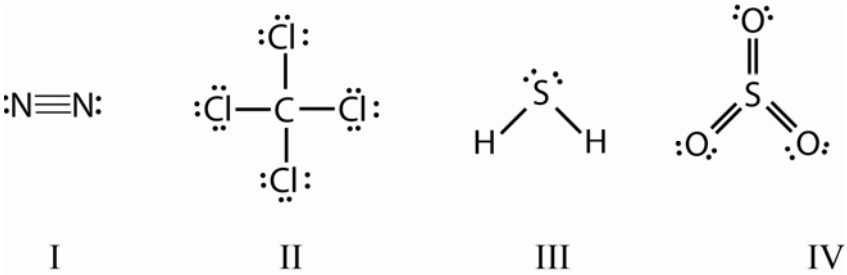
37. A 5-L sample of water contains 120 μg of lead. What is this lead concentration, in ppb?
A. 600
B. 417
C. 120
D. 24

38. Which of the molecules drawn below contains polar covalent bonds but is ***not*** a polar molecule?



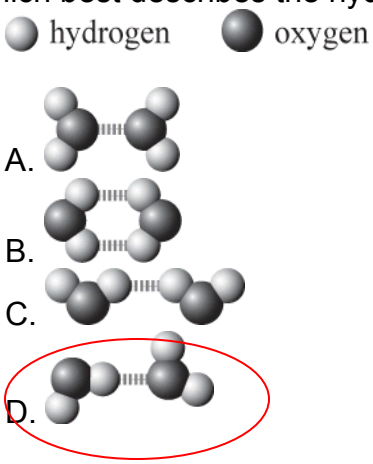
I II III IV

A. **I** only
B. **III** only
C. **II** and **IV** only
D. **I** and **III** only

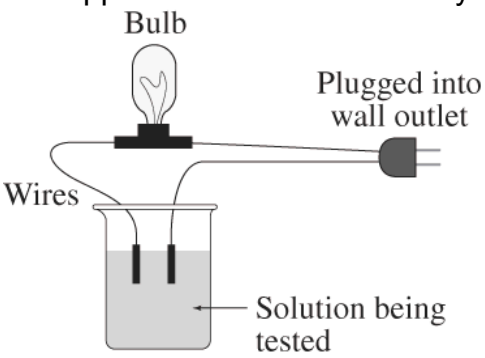
39. What is the molarity of sodium chloride in a solution containing 0.50 mol of sodium chloride in 500 mL of water?

A. 0.25 M
B. 0.50 M
C. 1.0 M
D. 5.0 M

40. Which best describes the hydrogen bonding between two water molecules?



41. A 0.25 M aqueous solution of sodium chloride, NaCl, is tested for conductivity using the type of apparatus shown. What do you predict will happen?

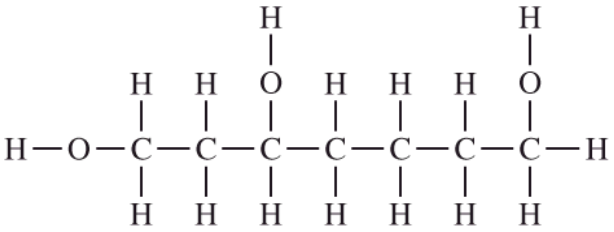


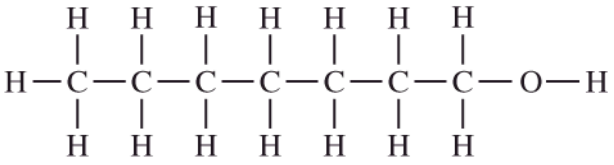
A. The bulb will not light up. NaCl does not dissolve in water.
B. The bulb will not light up. NaCl is in the molecular form in aqueous solution.
C. The light bulb will shine dimly. NaCl is only partially ionized in aqueous solution.
D. The light bulb will shine brightly. NaCl is highly ionized in aqueous solution.

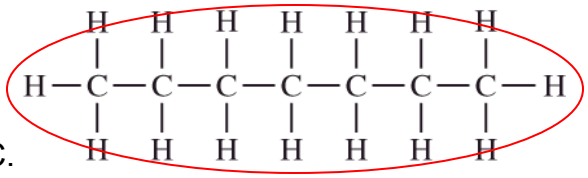
42. The main reason that water supplies are “chlorinated” is

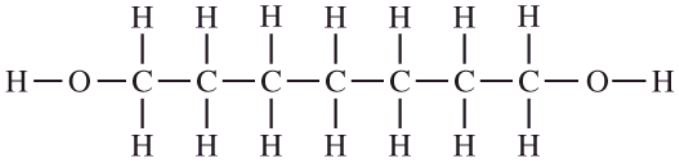
A. to filter out solids from the water.
B. to kill bacteria in the water.
C. to make the water softer.
D. to remove lead salts from the water as insoluble lead chloride.

43. Which compound should be the least soluble in water?

A. 

B. 

C. 

D. 

44. When a solution of ethanol, C_2H_5OH, is formed in water, the ethanol molecules
- A. are attracted to the nonpolar water molecules.
- B. form hydrogen bonds to the polar water molecules.
- C. form covalent bonds to the polar water molecules.
- D. are not attracted to the polar water molecules.

45. Which of these is ***not*** a trihalomethane?
- A. $CHCl_3$
- B. $CHBr_2Cl$
- C. CHF_3
- D. CH_3Cl

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46. Which naturally occurring radioactive particles are negatively charged?
- A. alpha particles
- B. beta particles
- C. gamma radiation
- D. neutrons

47. If you have 200.0 g of radioisotope with a half-life of 5 days, how much isotope would remain after 15 days?
A. 12.5 g
B. 13.3 g
C. 25.0 g
D. 40.0 g

48. How much energy is created from the conversion of 1.0×10^{-4} kg of matter?
A. 3.0×10^{4} J
B. 3.0×10^{7} J
C. 9.0×10^{12} J
D. 9.0×10^{15} J

49. Which is true about radioactivity? Radioactivity
A. is used to treat certain cancers.
B. damages white blood cells.
C. deforms DNA.
D. All of these choices are true.

50. Which is ***not*** a suitable option for the disposal of spent nuclear fuel?
A. Seal it in deep pools.
B. Monitor it in storage near the ground surface.
C. Bury it deep within the Earth.
D. Seal it in a landfill.

51. Which is a balanced equation for the fission of U-235?
A. $^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \longrightarrow {}^{137}_{52}\mathrm{Te} + {}^{97}_{40}\mathrm{Zr}$
B. $^{235}_{92}\mathrm{U} \longrightarrow {}^{144}_{55}\mathrm{Cs} + {}^{90}_{37}\mathrm{Rb} + {}^{1}_{0}\mathrm{n}$
C. $^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \longrightarrow {}^{87}_{35}\mathrm{Br} + {}^{146}_{57}\mathrm{La} + 3\,{}^{1}_{0}\mathrm{n}$
D. $^{235}_{92}\mathrm{U} \longrightarrow {}^{138}_{56}\mathrm{Ba} + {}^{95}_{36}\mathrm{Kr} + {}^{1}_{0}\mathrm{n}$

52. Thermal pollution is possible at water sources near
A. coal-burning plants.
B. nuclear plants.
C. both coal-burning and nuclear plants.
D. neither coal-burning or nuclear plants.

53. Breeder reactors
A. convert spent fuel rods into useful fuel.
B. produce Pu-239, which cannot penetrate human skin.
C. produce Pu-239 which can be used to build nuclear weapons.
D. All of the choices are true.

54. Which fact is ***not*** important when drawing conclusions from C–14 dating?
A. Living organisms exchange carbon with the atmosphere.
B. C–14 has a half-life of 5,730 years.
C. Dead organisms do not exchange carbon with the atmosphere.
D. C–14 emits beta particles.

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55. What is the primary determinant of the voltage developed by a battery?
A. The nature of the materials in the reaction.
B. The age of the battery.
C. The overall size of the galvanic cells.
D. The size of the electrodes.

56. A fuel cell does not "run down" like a standard battery because
A. the reactants in a battery must be stored inside the battery whereas the reactants for a fuel cell flow in as needed.
B. a fuel cell continually recycles the same electrons whereas a battery must continually generate new ones.
C. a battery is completely dependent upon oxidation-reduction reactions whereas a fuel cell depends on acid-base reactions.
D. a battery has many moving parts, whereas a fuel cell has none.

57. The aluminum-air battery is being considered for use in automobiles. In this battery, aluminum metal undergoes oxidation to Al^{3+} ions and forms $Al(OH)_3$. O_2 from the air undergoes reduction to OH^- ions. Which half-reaction occurs at the anode?
A. reaction of Al^{3+} ions with hydroxide ions to produce $Al(OH)_3$.
B. capturing O_2 from the air so that it may form the OH^- ions.
C. formation of OH^- ions from O_2.
D. formation of Al^{3+} ions from aluminum.

58. Silicon has 4 electrons in its outer energy level, arsenic has 5. Adding small amounts of arsenic to pure silicon
A. destroys the ability of the silicon to act as a semiconductor.
B. provides the basis for using the silicon as a fuel cell.
C. creates a *p*-type semiconductor.
D. creates an *n*-type semiconductor.

59. Which increases the efficiency of a photovoltaic or solar cell?
I. Replacing crystalline silicon with its non-crystalline form.
II. Increasing the number of alternating *p*- and *n*-type layers of semiconductors.
III. Decreasing the thickness of each alternating *p*- and *n*-type layer of semiconductor.
A. **I** and **II** only
B. **II** and **III** only
C. **I** and **III** only
D. **I**, **II** and **III**

60. Which has ***not*** been suggested as a reasonably practical way to store large amounts of hydrogen in relatively small spaces for its use as a fuel?

A. Encapsulate hydrogen molecules in fullerene molecules (large, carbon based molecules which can act like cages) that may be later heated to release the hydrogen.
B. Store it in the form of ionic metal hydrides, such as LiH, which release hydrogen gas when they react with water.
C. Liquefy hydrogen under pressure and store it much as we do with liquefied natural gas today.
D. Absorb hydrogen onto activated charcoal; then heat the mixture to release the hydrogen.

61. Which type of widely used battery is ***not*** rechargeable?

A. alkaline
B. lithium-ion
C. lead-acid (storage batteries)
D. nickel-cadmium (NiCad)

62. Chemical energy is converted directly into electrical energy in

A. a battery.
B. an electrical power plant.
C. an electrolytic cell.
D. an automobile's engine.

63. Which is ***not*** true about Toyota's hybrid car, the Prius?

A. It should never need to be connected to an external electrical outlet to charge its batteries.
B. Despite its efficiency, it produces about the same amount of CO_2 and a bit more NO_x than Toyota's traditional vehicle.
C. Upon braking, the vehicle is designed to transfer the kinetic energy of the car to a generator which charges the batteries.
D. It was available in Japan for some time before coming to the U.S.

Congratulations!
Have a great summer.

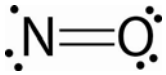
Bonus Problems (5 points each)

1) Assume that an extremely inefficient electrical utility company delivers electrical energy to your home from a natural gas-burning power plant with an overall efficiency of only 21% and your furnace is 100% efficient in converting electrical energy into heat energy. What mass of natural gas must be burned by the power plant if heating your home requires 3.5×10^7 kJ? The heat of combustion of natural gas is 50.1 kJ/g.

3.5×10^7 kJ is required at your house, and natural gas produces 50.1 kJ/g. So, you need to burn 3.5×10^7 kJ/50.1 kJ/g = $7x10^5$ g of natural gas. However, the conversion at the power plant is very inefficient – you only get 21% as much energy as you should. So, you need to burn a lot more. How much? $7x10^5$ g/21% = $3.3x10^6$ g, or $3.3x10^3$ kg.

2) NO, nitrogen monoxide, is a radical which plays crucial roles in the atmosphere, but also in the human body, where it serves as a messenger for muscles and for blood flow.
a) Draw the best possible Lewis structure for NO
b) Describe what happens to NO when it absorbs an infrared photon.
c) Describe what happens to NO when it absorbs an ultraviolet photon.
d) Identify which region of the electromagnetic spectrum is represented by these three photons, each of which is absorbed by NO: 6000 nm, 550 nm, 220 nm.
e) Speculate as to what might happen to the NO molecule when it absorbs the *third* photon described in (d).

a) This is a radical, but we can do the best we can:



b) Infrared photons cause molecules to vibrate. The double bond in NO will expand and contract.

c) UV photons cause bonds to break. One or both of the bonds between N and O will break.

d) 6000 nm is infrared, 550 nm is visible, and 220 nm is UV.

e) The visible photon will excite electrons within the bonds. In the case of weakly bound radicals, this will sometimes cause the bond to break. But because we have a double bond here, that is unlikely.

3) In the methane fuel cell, methane replaces hydrogen as the fuel. Balance the two half-reactions and write the overall reaction for the processes in a methane fuel cell:

Anode: $CH_4 + OH^- \rightarrow CO_2 + H_2O + e^-$

Cathode: $O_2 + H_2O + e^- \rightarrow OH^-$

This is straight out of Homework 10.

Oxidation:

$CH_4 + OH^- \rightarrow CO_2 + H_2O + e^-$

At the moment, we have 5 H atoms on the left and 2 on the right. Clearly, we need more on the right, but we also need an even number on the left if we're ever going to get this balanced. Let's try adding one more OH- to the left, to give us a total of 6 Hs on the left, thus requiring 3 H2Os on the right:

$CH_4 + 2\ OH^- \rightarrow CO_2 + 3\ H_2O + e^-$

This isn't bad, but now the oxygen isn't balanced. We need to add OH- to the left to increase the number of Os, but that will also require us to add H2O to the right... which also has O. The easiest way to do this is to just use trial and error – keeping in mind that we can only have even numbers of H on the right, and we're STARTING with 6 on the left. In the end, the O and H are balanced when we have:

$CH_4 + 8\ OH^- \rightarrow CO_2 + 6\ H_2O + e^-$

We still need to balance our charges – we have 8 negative charges on the left, so we need to add 7 more to the right:

$CH_4 + 8\ OH^- \rightarrow CO_2 + 6\ H_2O + 8\ e^-$

Reduction:

$O_2 + H_2O + e^- \rightarrow OH^-$

We need to end up with an equal number of Hs and Os on the left hand side, because all we have on the right is hydroxide. Adding a second water gives us a total of 4 Os and a total of 4 Hs. That's the way to go:

$O_2 + 2\ H_2O + e^- \rightarrow 4\ OH^-$

Now we have 4 negative charges on the right, but only one on the left, so we need:

$O_2 + 2\ H_2O + 4\ e^- \rightarrow 4\ OH^-$

Overall:

To make the overall reaction balance, we need to make sure that the electrons balance. In this case, it's pretty easy – the Oxidation reaction uses 8 electrons, but the Reduction only uses 4. If we double the Reduction reaction, the electrons will balance:

Ox: $CH_4 + 8\ OH^- \rightarrow CO_2 + 6\ H_2O + 8\ e^-$

Red: $2\ O_2 + 4\ H_2O + 8\ e^- \rightarrow 8\ OH^-$

Total: $CH_4 + 8\ OH^- + 2\ O_2 + 4\ H_2O \rightarrow CO_2 + 6\ H_2O + 8\ OH^-$

But now we have some things that appear on both sides of the equation! OH- and H2O. Let's cancel those out and see what's left:

$$CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$$