Chemistry (Environmental Studies) L111
Environmental Concerns and Chemical Solutions
Professor Dransfield
Exam 3
May 10, 2007

Name_____

Student ID Number _____

Statistics

Total Point Available = 200 + 15 bonus

25 Exams Scored

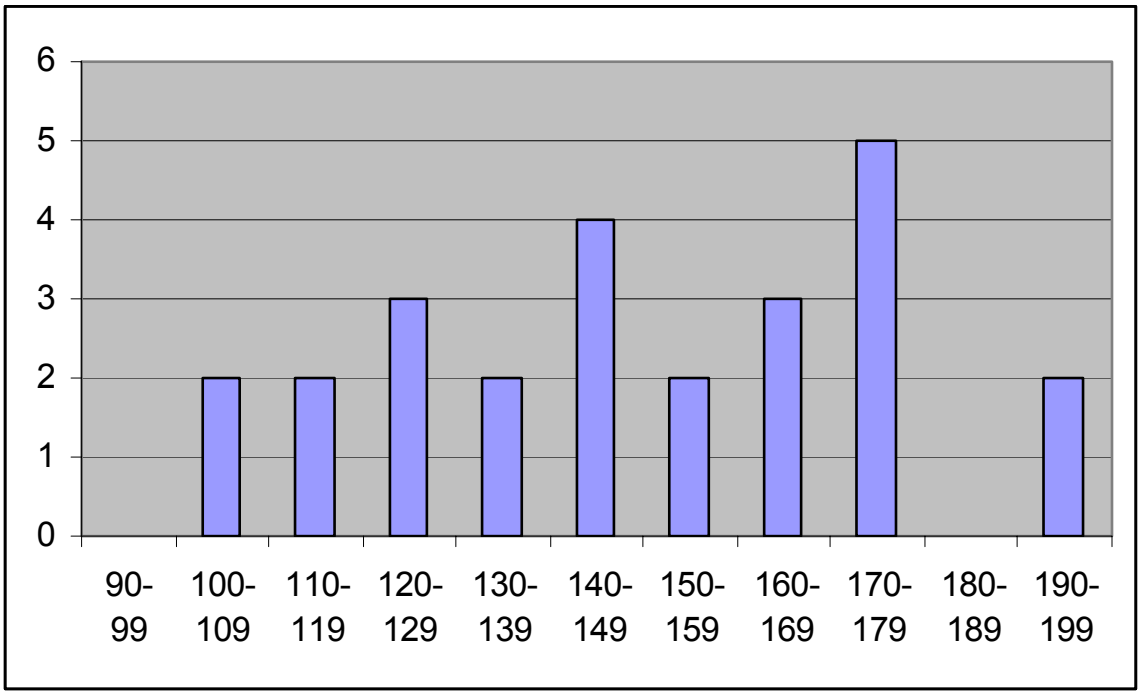
Average = 149

Median = 148

Standard Deviation = 26.6

High = 194

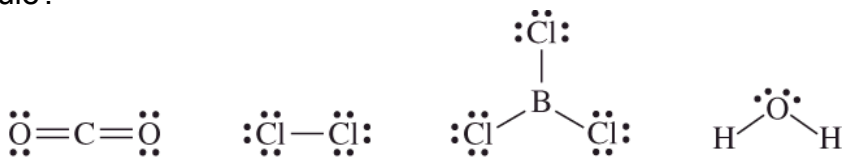
Low = 105



1. A 4-L sample of water contains 80 μg of lead. What is this lead concentration, in ppb?

a. 20 **12/25 (even though we've had this one before)**
b. 80
c. 320
d. 500

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



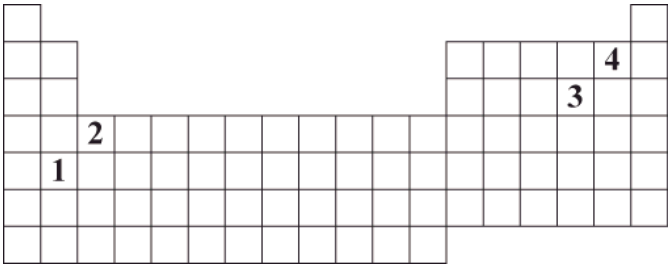
I II III IV

a. **I** only
b. **III** only
c. **I** and **III** only **6/25 (even though we've had this one before)**
d. **II** and **IV** only

3. 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. 21/25
c. form covalent bonds to the polar water molecules.
d. are not attracted to the polar water molecules.

4. Numbers 1–4 are used to identify four different elements. Based on the organization within the periodic table, which element is expected to have 2+ charge when it forms an ion?



a. 1 16/25
b. 2
c. 3
d. 4

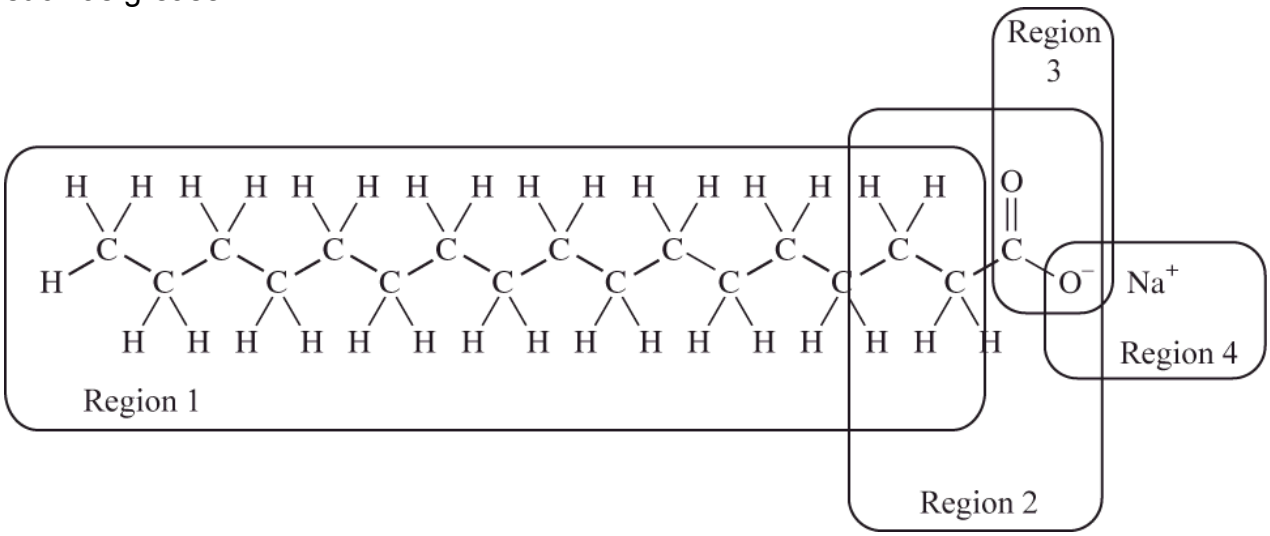
5. What is the formula of the ionic compound formed between magnesium, Mg, and chlorine, Cl?

a. MgCl
b. Mg_2Cl_2
c. Mg_2Cl
d. $MgCl_2$ **15/25 (even though we've had this one before)**

6. Which of these is ***not*** a trihalomethane?
   a. $CHCl_3$
   b. CH_3Cl **14/25 (even though we've had this one before)**
   c. CHF_3
   d. $CHBr_2Cl$

7. Which of these substances in drinking water pose a health risk?
I. Lead in water
II. Hard water ions
III. Trihalomethanes in water
   a. **I** only
   b. **II** only
   c. **I** and **II** only
   d. **I** and **III** only 22/25

8. Which region of the soap molecule shown dissolves most easily in nonpolar materials such as grease?



   a. Region 1 7/25 This one's hard. Grease is nonpolar, which means it will dissolve other things which are nonpolar. The least polar part of this molecule is Region 1.
   b. Region 2
   c. Region 3
   d. Region 4

9. What are the major disadvantages of using ozone, in place of chlorine, to disinfect water?
   a. Ozonation is more expensive than chlorination and ozone leaves an odor in the water.
   b. Ozonation forms trihalomethanes in the treated water and leaves an odor in the treated water.
   c. Ozonation forms trihalomethanes and is more expensive than chlorination.
   d. Ozonation is less effective against water-borne viruses and is more expensive than chlorination. **11/25**

10. What percent of the Earth's water is in the oceans?
    a. 97.4% 25/25 Yay!
    b. 50%
    c. 2.59%
    d. 0.014%

11. Which of these is **not** a realistic risk associated with nuclear power plants?
    a. storage of spent fuel rods
    b. a meltdown from loss of coolant
    c. the likelihood of nuclear explosion 24/25
    d. thermal pollution of the coolant source

12. The half-life of carbon-14 is 5,730 years. If you started with 100.0 g of carbon-14, how much would remain after 4 half-lives?
    a. 25.0 g
    b. 12.5 g
    c. 6.25 g 19./25
    d. 57.3 g

13. Which would contribute most to your annual radiation exposure?
    a. living at an elevation 1,000 m above sea level
    b. smoking a pack and a half of cigarettes per day 16/25
    c. having a dental X-ray
    d. living within 50 miles of a nuclear reactor

14. Which is a balanced equation for the fission of U-235?

a. $^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{87}_{35}\mathrm{Br} + {}^{146}_{57}\mathrm{La} + 3\,{}^{1}_{0}\mathrm{n}$ **10/25**

b. $^{235}_{92}\mathrm{U} \rightarrow {}^{138}_{56}\mathrm{Ba} + {}^{95}_{36}\mathrm{Kr} + {}^{1}_{0}\mathrm{n}$

c. $^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{137}_{52}\mathrm{Te} + {}^{97}_{40}\mathrm{Zr}$

d. $^{235}_{92}\mathrm{U} \rightarrow {}^{144}_{55}\mathrm{Cs} + {}^{90}_{37}\mathrm{Rb} + {}^{1}_{0}\mathrm{n}$

The trick here is that fission has to be initiated by a neutron. a+d both balance, but only a is neutron-initiated.

15. 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 13/25 – I forgot to remind you that 1 J = 1 kg m^2/s^2
    d. 9.0×10^{15} J

16. Which is the best critique of the following statement?
"Radioactivity is so dangerous that we should do all we can to completely eliminate our exposure."
   a. Somewhat true. Although any exposure to radioactivity is potentially deadly, there is nothing we can do to avoid it so we must be resigned to the risk.
   b. Somewhat true. Radioactivity can be dangerous, but in some circumstances, exposure to it is unavoidable, so zero exposure is not a reasonable goal. 23/25!
   c. Not true. We should not fear radioactivity because it is a natural part of life.
   d. Absolutely correct. Radioactivity is the ultimate danger and we should keep our exposure to zero.

17. For safety reasons, high-level nuclear waste (HLW) must be contained
   a. for 10 years.
   b. for 100 years.
   c. until it becomes low-level nuclear waste.
   d. permanently. 16/25

18. Most high-level nuclear waste in the U.S. is currently
   a. sealed deep within the Earth.
   b. encased in glass and buried near the surface.
   c. sealed in deep pools at the sites where it was produced. 21/25
   d. stored at breeder reactors waiting for reprocessing.

19. Which type of power plant is responsible for more fatalities annually?
   a. nuclear plants
   b. coal-burning plants 20/25
   c. Neither nuclear or coal-burning plants cause fatalities.
   d. Fatalities are substantially the same at both nuclear and coal-burning plants.

20. The greatest percentage of background radiation comes from
   a. nuclear power plants.
   b. medical X-rays.
   c. living things.
   d. radon. 15/25

21. Which naturally occurring radioactive particles are the largest?
   a. alpha particles **10/25!**
   b. beta particles
   c. gamma radiation
   d. neutrons

22. Which is ***not*** true of radioactive half-life? Radioactive half-life is
   a. the time required for the level of radioactivity in a sample to be cut in half.
   b. independent of the amount of radioactive material present.
   c. increased by heating the isotope. 19/25
   d. independent of the physical or chemical form of the isotope.

23. Which is ***not*** considered to be low-level radioactive waste?
   a. clothing for workers administering nuclear medicine
   b. smoke detectors
   c. spent fuel rods 23/25
   d. radioactive pharmaceuticals

24. Which is the biggest impediment to storing low-level radioactive waste?
   a. lack of proper barrels
   b. economically feasibility
   c. lack of proper technology
   d. political opposition 16/25

25. Which is ***not*** a reason for the decline in the reliance on nuclear power for electricity generation in the U.S. over the last 30 years?
   a. a lack of available nuclear fuel 17/25
   b. the need for enhanced safety training for workers
   c. the need to retrofit old plants
   d. an increase in the required number of qualified personnel

26. The primary reason countries world wide have turned to nuclear power for electricity generation is to reduce
   a. the greenhouse effect.
   b. acid rain.
   c. their reliance on fossil fuels. 22/25
   d. the damage caused by strip mining.

27. Which is a characteristic of "surface" high-level nuclear waste storage that is ***not*** a characteristic of storing the waste in a geological repository?
   a. easily recovered 19/25
   b. feasible
   c. secure
   d. safe

28. What type of radiation is given off in this nuclear reaction?

$$^{14}_{6}\mathrm{C} \rightarrow {}^{14}_{7}\mathrm{N} + \_\_\_\_$$

   a. alpha
   b. beta 20/25
   c. gamma
   d. neutron

29. Which feature or process is unique to nuclear power plants when compared to conventional coal-burning power plants?
   a. formation of steam
   b. smoke stacks
   c. generators
   d. control rods 25/25!

30. Which does **not** contribute to your annual radiation dose?
   a. the number of dental X-rays you get each year
   b. the number of hours you spend listening to the radio 24/25
   c. the type of structure you live in
   d. the amount of time you spend riding in jet planes

31. The opposite of a galvanic cell is
   a. a battery.
   b. a fuel cell.
   c. an electrolytic cell. 23/25
   d. a photovoltaic (solar) cell.

32. Which is ***not*** a current or planned use for the electricity generated by fuel cells?
   a. to control nuclear fusion 22/25
   b. as the output of small power plants
   c. to operate space shuttles
   d. to power a cell phone

33. In an electrochemical cell, the anode is
   a. the material used to connect the two half cells to each other.
   b. always used up before the cathode.
   c. never a metal.
   d. the electrode at which oxidation takes place. 23/25

34. Which is ***not*** a necessary consideration for a battery designed to run a cell phone or portable MP3 player?
   a. It must develop a useful level of electrochemical potential.
   b. It must "run" for a reasonable amount of time.
   c. It must use liquid, aqueous solutions. 20/25
   d. It must be fairly light in weight.

35. What is the primary determinant of the voltage developed by a battery?
   a. The nature of the materials in the reaction. 16/25
   b. The age of the battery.
   c. The overall size of the galvanic cells.
   d. The size of the electrodes.

36. Very small mercury batteries have been made and used in a multitude of applications.
Why have they been replaced by other kinds of batteries for most applications?

a. Mercury has become far too expensive to use in batteries.
b. Mercury is poisonous and difficult to dispose of. 24/25
c. These batteries cannot generate enough current for any modern devices.
d. Though they may be made very small, they are far too heavy to use in most applications.

37. A fuel cell does not "run down" like a standard battery because

a. a fuel cell continually recycles the same electrons whereas a battery must continually generate new ones.
b. a battery is completely dependent upon oxidation-reduction reactions whereas a fuel cell depends on acid-base reactions.
c. a battery has many moving parts, whereas a fuel cell has none.
d. the reactants in a battery must be stored inside the battery whereas the reactants for a fuel cell flow in as needed. 14/25

38. In general, a modern hybrid vehicle is less polluting than a standard vehicle because it runs on both a

a. gasoline engine and an electric motor run by a rechargeable battery. 22/25
b. gasoline engine and a fuel cell.
c. fuel cell and an electric motor run by a rechargeable battery.
d. gasoline engine and a cleaner diesel engine.

39. 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. **10/25**
c. Upon braking, the vehicle is designed to transfer the kinetic energy of the car to a generator which charges the batteries.
d. The gasoline engine and electric motor are used during normal driving and the batteries are used for a boost during quick acceleration.
Note: here, I take some blame. d) also disagrees with the way I presented the material, but I was apparently wrong. Sorry about that! Good thing this exam is curved.

40. At present, it will be difficult and perhaps inappropriate to develop an economy based on burning hydrogen rather than natural gas or gasoline because

a. hydrogen is a dirty fuel. Burning hydrogen produces significantly more pollutants than burning natural gas or gasoline.
b. hydrogen is not an efficient fuel. Per gram, hydrogen has about the lowest heat of combustion of any known substance, much lower than natural gas or gasoline.
c. although hydrogen is abundant, pure hydrogen is not found naturally on earth. Hydrogen is difficult or expensive to isolate and collect. 24/25

d. being such a light element, hydrogen will not flow through pipelines the way natural gas or gasoline do. Hydrogen cannot easily be delivered from where it is produced to the places where it is needed.

41. 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. Liquefy hydrogen under pressure and store it much as we do with liquefied natural gas today. 13/25
b. Absorb hydrogen onto activated charcoal; then heat the mixture to release the hydrogen.
c. Store it in the form of ionic metal hydrides, such as LiH, which release hydrogen gas when they react with water.
d. Encapsulate hydrogen molecules in fullerene molecules (large, carbon based molecules which can act like cages) that may be later heated to release the hydrogen.

42. Sunlight (solar radiation) may be turned directly into electricity using

a. fuel cells.
b. electrolytic cells.
c. lead-acid cells.
d. photovoltaic cells. 24/25

43. Semiconductors such as the element silicon may be used in cells that convert solar radiation to electricity. One of the major difficulties encountered in using silicon is that

a. it is one of the rarest of all elements and therefore difficult to find on earth.
b. it is expensive to produce large quantities of extremely pure silicon. 23/25
c. it quickly evaporates when isolated in a pure state.
d. it is the most active of all the elements, so it cannot be prepared in a pure state.

44. The “doping” of a semiconductor to improve its performance means

a. slightly raising the temperature of a pure semiconductor to improve the ability of its electrons to flow from atom to atom.
b. fusing layers of two different pure semiconductors together to give the electrons that absorb the solar radiation characteristics of the electrons of both semiconductors.
c. mixing large amounts of a metal with small amounts of a semiconductor so that the metal itself becomes a semiconductor.
d. adding small amounts of other elements to the pure semiconductor to change the freedom of electron motion throughout the crystal. 21/25

45. Silicon has 4 electrons in it outer energy level, gallium has 3. Adding small amounts of gallium 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. 14/25
d. creates an *n*-type semiconductor.

46. In a solar cell, placing semiconductors of the *p*-type and *n*-type in contact with each other via a conducting wire accomplishes two things.

a. It ensures that only certain energies of solar radiation cause electricity to flow as it facilitates the conduction of electricity.
b. It ensures that only certain energies of solar radiation cause electricity to flow as it facilitates the flow of electricity in either direction.
c. It ensures that only oxidation takes place as it facilitates the conduction of electricity.
d. It ensures that the current flows in a specific direction as it facilitates the conduction of electricity. 21/25

47. 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** **11/25!**

48. Batteries must be used in addition to solar cells when generating household electricity because

a. batteries must supply the energy when sunlight is not available. 21/25
b. solar cells can generate electricity only via the output of a battery.
c. solar cells can generate only a small fraction of the total energy needed by a household at any one time.
d. solar cells generate so much electricity that they will overheat if they cannot transfer the excess electricity somewhere to dissipate the extra heat.

49. 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. formation of OH^- ions from O_2.
b. capturing O_2 from the air so that it may form the OH^- ions.
c. formation of Al^{3+} ions from aluminum. **12/25!**
d. reaction of Al^{3+} ions with hydroxide ions to produce $Al(OH)_3$.

50. Whenever a substance is oxidized,

a. it is called the oxidizing agent.
b. some other substance must be reduced. 20/25
c. it gains electrons.
d. H^+ ions are produced.

Bonus Problems (5 points each)

1) Rather than specifying the aqueous concentration of the ions, we report "hardness" in mg/L – how much calcium carbonate **could** be formed from the ions present IF sufficient carbonate ions were present (an unlikely occurrence). The balanced reaction is:

$$Ca^{2+}(aq) + CO_3^{2-}(aq) \rightarrow CaCO_3(s)$$

If the hardness of a given sample of water was 60 mg/L ("moderately hard"), what is the concentration of Ca^{2+} ions in moles/L?

First off, let's make the simplifying assumption that we have 1 L of solution. At 60 mg/L of $CaCO_3$, that means 60 mg of $CaCO_3$ in our 1 L, and 60 mg is 0.060 g. (+1)

$CaCO_3$ has a molecular weight of 40.08 (Ca) + 12.011 (C) + 3*16.00(3 O) = 100.091 g/mole. (+1)

0.060 g / 100.091 g/mole = 0.000599 moles of $CaCO_3$ in our liter sample. (+1)

Every mole of $CaCO_3$ had to come from somewhere – and it had to come from a mole of Ca^{2+}. So .000599 moles of $CaCO_3$ in the test result means that there were 0.000599 moles of Ca^{2+} in the original sample. (+1)

0.000599 moles of Ca^{2+} in 1 L means a molarity of 0.000599 M. (+1)

2) The first step in the radioactive decay of U-238 is alpha emission to form Thorium 234. If a mole of U-238 undergoes this decay, how much energy is released?
U-238 has an atomic mass of 238.003 g/mole; Th-234 has a mass of 233.9942 g/mole; He-4 has an atomic mass of 4.0015 g/mole.

First things first: we need to balance the equation. We should know that an "emission" of an alpha particle means that the He nucleus is going on the product side. That makes the equation look like this:

$$^{238}_{92}U \rightarrow ^{234}_{90}Th + ^{4}_{2}He \qquad (+1)$$

So, the mass of the reactants is just the mass of U-238 (238.003) and the mass of the products is 233.9942 + 4.0015 = 237.9957. (+1)

So the change in mass is products – reactants, 237.9957 – 238.0003 = -0.0073. (+1)

The Einstein equation tells us that $E = mc^2$
Applied here, that means that $E = -(0.0073\ g)*(3.00\ m/s)^2$ (+1)
$= -6.6*10^{11}\ kgm^2/s^2 = -6.6*10^{11}$ J (negative because it's exothermic) (+1)

*Note: There's a typo in the problem. The actual mass of U-238 is 238.00**0**3, which produces an actual E of $4.1*10^{11}$ J*

Bonus Problems, Continued (5 points each)

3) Hydrogen gas can be prepared in the lab by reacting metallic sodium with water, as shown in the following equation:

$$2\ Na(s) + 2\ H_2O(l) \rightarrow H_2(g) + 2\ NaOH(aq)$$

If the hydrogen gas produced is burned in a fuel cell, it will provide 286 kJ/mole of energy. The average American consumes 1.1×10^6 kJ of energy per day. How many grams of sodium per day must be consumed in the reaction above to support one average American? Is this a viable and sustainable way to produce H_2 fuel for society?

If we need $1.1*10^6$ kJ per day, and we get 286 kJ/mole of H_2 burned, then we need $1.1*10^6/286$ moles of H_2, which is 3846.1 moles. (+2)

Because the balanced equation requires 2 moles of Na to be consumed for every mole of H2 produced, we need 2x3846.1 = 7692.3 moles of Na. (+1)

Sodium weighs 22.99 grams/mole, so 7692.3 moles of Na weigh 7692.3x22.99 = 176846 grams, or 176.8 kg. (+1)

Given that we would need to consume that much sodium **per person *per day*,** this is definitely NOT a viable or sustainable way to proceed. (+1)