# Exam Calculations for IPOL 512 Fall 2012

1. Do equation-based and unit analysis calculations.
2. Do calculations using the equations for volumes and surface areas of common geometric shapes.
3. Convert between regular decimal numbers and numbers expressed in scientific notation.
4. Do calculations involving adding, subtracting, multiplying, dividing, and taking powers of exponential numbers.
5. Convert among the common temperature scales; Fahrenheit, Celsius, and Kelvin.
6. Use the rules of significant figures to round numbers derived from calculations.
7. Do unit conversions for the following types of unit conversions
   a. SI→SI (using your knowledge of the metric prefixes)
   b. L ↔ gal (3.785 L per gal)
   c. g ↔ lb (453.6 g per lb)
   d. cm ↔ in. (2.54 cm per in.)
   e. Squared and cubed units
   f. Density as a conversion factor
   g. Percentages as conversion factors
   h. Anything that can be expressed as "something per something" can be expressed as a ratio that can be used as a conversion factor.
   i. Use molar mass to convert between moles and mass
   j. Mass biomass ↔ mass carbon in that biomass (about 0.4 g C per g biomass)
   k. kg biomass ↔ MJ (16 MJ per kg biomass)
   l. g C in biomass ↔ kJ (40 kJ per g carbon in biomass)
   m. mass ice ↔ volume ice (using 0.92 g/mL)
   n. mass liquid water ↔ volume liquid water (using 1.0 g/mL)
   o. g air ↔ mol air (29 g air per mole air)
   p. From one energy unit to another
      J ↔ cal ↔ Btu ↔ kWh ↔ quad
   q. Use molar volume to convert between volume of gas and moles of gas
   r. Acre-foot ↔ $m^3$ (1233 $m^3$ = 1 acre-foot)
   s. Mass ratio ↔ ppm(mass) or ppm(w)
   t. Volume ratio ↔ ppm(v)
   u. W (solar irradiance) ↔ $m^2$
8. Given two of the following for a steady state system, calculate the third: stock, flow rate, and time.
9. Given two of the following three values, calculate the third: energy, power, and time.
10. Do calculations involving the energy stocks of fossil fuels, the rate of consumption, and the time they will last.
11. Do calculations involving net primary productivity (NPP), including (1) conversions between NPP described in mass of carbon per year and NPP in terms of power (e.g. TW), (2) conversions between NPP described in mass of carbon per year and energy per year (e.g. in J/yr), and (3) conversions between mass of carbon per year and mass of biota.
12. Convert between amount of compound and amount of element in that compound.

13. Convert between moles of substance and number of particles, using Avogadro's number.
14. Given three of the following four values and the universal gas constant, calculate the fourth value: gas pressure, volume, moles, and temperature.
15. Using the trigonometry function of tangent, and given two of the following three values of a triangle, calculate the third value: angle, length of opposite side, and length of adjacent side.
16. Calculate stocks for the following situations.
    a. Steady State
       $S(t) = S_0 = Ft$
    b. $F_{in}$ - $F_{out}$ = constant
       $S(t) = S_0 + \Delta Ft$
    c. Exponential Growth of Stocks
       $S(t) = S_0 e^{rt}$
    d. Exponential decline (decay) of Stocks
       $S(t) = S_0 e^{-rt}$
    e. Exponential growth of outflows
       $S(t) = S_0 - \frac{F_0}{r}(e^{rt} - 1)$
17. Use the coefficients in a balanced equation to convert between moles of one substance and moles of another, both involved in a chemical reaction.
18. Use the species-area equation, $S = cA^z$, to calculate the number of species in an area. (You would be given *c* and *z* and enough information to determine *A*.)
19. Calculate doubling time for exponential growth.
20. Calculate the half-life for exponential decay.
21. Use box diagrams to organize calculations. (See problems 5 and 6 of homework 4.)
22. Given Planck's constant and the speed of light and either the energy of a photon or its wavelength, calculate the one not given.
23. Do calculations that involve the different ways that ozone levels can be described: Dobson units, molecules/cm$^2$, moles/cm$^2$, molecules/cm$^3$, and $\mu$g/m$^3$.

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24. Do unit analysis calculations using the average density of coal use in the U.S. (100 t/km$^2$/y), the average percent sulfur in coal (2.5%), the emission density of sulfur from coal (2.5 g(S)/m$^2$/y), the emission of sulfur from coal deposited as $H_2SO_4$ (0.6 g(S)/m$^2$/y), the emission density of nitrogen in nitrogen oxides (1.5 g(N)/m$^2$/y), and the wet deposition as nitrogen as nitric acid (0.23 g(N)/m$^2$/y).
25. Calculate the [$H^+$] and pH of precipitation containing 0.6 g(S)/m$^2$/y deposited as $H_2SO_4$ in the $\approx$1 m/y of precipitation.
26. Calculate the [H+] and pH of the rain if 0.23 g(N)/m$^2$/y are deposited as $HNO_3$ in $\approx$1 m/y of precipitation.
27. Calculate the [H+] and pH of the rain if 0.23 g(N)/m$^2$/y are deposited as $HNO_3$ and 0.6 g(S)/m$^2$/y are deposited as $H_2SO_4$ in $\approx$1 m/y of precipitation.
28. Do calculations using the ANC of a saturated calcium carbonate solution (970 $\mu$Eq/L).

29. Given the volume of a lake, the watershed area, and the pH of precipitation of 1 m/y, calculate (1) the change in the ANC of the lake in mEq $H^+$ per liter per year and (2) the mass of calcium carbonate that would need to be added to counteract the change.
30. Given two of the following three values, calculate the third: the concentration of the solute in mol/L, the partial pressure of the solute in the gas above the solution, Henry's constant for a gas/solvent combination.
31. Do calculation using the following equations.

$$[H^+][OH^-] = 1.0 \times 10^{-14}$$

$$[CO_2] = P_{CO_2}\ (0.03400\ \text{mol/L·atm}) = 1.34 \times 10^{-5}\ \text{mol/L} = [H_2CO_3^*]$$

$$K_{a1} = \frac{[H^+][HCO_3^-]}{[H_2CO_3^*]} = 4.6 \times 10^{-7}$$

$$K_{a2} = \frac{[H^+][CO_3^{2-}]}{[HCO_3^-]} = 4.69 \times 10^{-11}$$

$$[H^+] = [OH^-] + [HCO_3^-] + 2[CO_3^{2-}]$$

32. Using the equations above, calculate the pH of natural water.
33. Do calculations using the solubility product of calcium carbonate.

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

    $K_{sp} = [Ca^{+2}]\ [CO_3^{-2}] = 4.47 \times 10^{-9}$ mole$^2$/liter$^2$ in fresh $H_2O$
34. Given either the half-life or the decay constant for a radioactive nuclide, calculate the other.
35. Given all but one of the following, calculate the one not given: the amount of a radioactive substance initially ($S_0$), the amount at time t ($S_t$), the time (t), and the decay constant (k).
36. Given two of the following three, calculate the third: physical dose of a radioactive substance (in rads or grays), the relative biological effectiveness of the radiation, and the biological dose (in rems or Sieverts).
37. Given the radiation exposure in biological dose per time (e.g. mSv/h) and time of exposure, calculate the approximate increase in risk of cancer.
38. Given the LD-50 for a toxic chemical and a person's body mass, calculate the dose that has a 50% chance of killing the person.
39. Given the slope factor for a carcinogenic substance, the mass of a person, and the person's daily consumption, calculate the unit risk of the person getting cancer and the concentration that gives the person a one in a million chance of getting cancer.

Student Topics

Energy Balance Models

1. At present the emission temperature of the Earth is 255 K, and its albedo is 30%. How would the emission temperature change if:

    (a) the albedo were reduced to 10% (and all else were held fixed);

    (b) the infrared absorptivity of the atmosphere — $\epsilon$ in Fig.2.8 — were doubled, but albedo remains fixed at 30%.

2. Suppose that the Earth is, after all, flat. Specifically, consider it to be a thin circular disk (of radius 6370 km), orbiting the Sun at the same distance as the Earth; the planetary albedo is 30%. The vector normal to one face of this disk always points directly towards the Sun, and the disk is made of perfectly conducting material, so both faces of the disk are at the same temperature. Calculate the emission temperature of this disk, and compare with Eq.(2.4) for a spherical Earth.

Global Warming Potential

Given the mass of a greenhouse and its GWP value, calculate the $CO_2$ equivalent emissions of the gas.

Most important problems from homework sets

HW 1 – 3 (rate of erosion problem)

HW 2 – (COW page 17 exercise 1), 3 (raising sea level), 4 ($CO_2$ concentration), 6 (relating to COW I.6)

HW 3 – 3 (Indonesia land use), 4 (solar energy, etc.), 5 (fossil fuels and $CO_2$)

HW 4 – 1 (Exponential growth), 3 (nitrogen cycle), 4(a), 5, 6

HW 5 – all

HW 6 - all