CE 11 SP22 MT1

This quiz consists of 20 questions; each question is worth one point. The quiz is open-book/open-notes, you may consult course materials posted on the bCourses site for CE 11, and you may also use a calculator. Communication or collaboration with others is not allowed. You must answer these questions on your own. Some of the questions are easier than others, so if you get stuck, move on and come back to the more difficult questions later if you have time.

1. Select the ion present in seawater that corresponds to each of the listed cation and anion categories. Note bivalent ions have a charge of 2+ or 2-.
    a. **Most abundant cation → Sodium Ion**
    b. **Most abundant anion → Chloride Ion**
    c. **Bivalent cation → Magnesium Ion**
    d. **Bivalent anion → Sulfate Ion**

2. Which of the following methods can be used to desalinate salty water? Select all that apply.
    a. **Boiling (the vapor phase that forms will be salt-free)**
    b. Exposing water to ultraviolet radiation
    c. Subjecting water to a magnetic field
    d. **Freezing (the solid phase that forms will be salt-free)**

3. Which of the following factors have contributed to observed sea level rise in recent decades? Select all that apply.
    a. **Thermal expansion of sea water as it warms**
    b. **Melting of Greenland and Antarctic ice sheets and mountain glaciers**
    c. Increased fraction of precipitation falling as snow rather than rain
    d. Increased amount of precipitation falling on land areas

4. Calculate the amount of heat that must be added to convert 5 kg of ice at 0˚C to 5 kg of liquid water at 55˚C. The latent heat of melting for ice is 333 kJ/kg, and the heat capacity of water is 4.2 kJ / (kg ˚C). Round your answer to the nearest whole kJ, but enter only a numerical value (do not include the kJ units as part of your answer).

Answer: Given: m_{ice} = 5 kg
T_1 = 0 ˚C
T_2 = 55 ˚C
Δh_m = 333 kJ/kg (latent heat of melting)
$C_{p,H2O}$ = 4.2 kJ/(kg ˚C) (heat capacity of water)

From ***L02: Oceans and Desalination***, we know the equation for finding the heat (Q) needed to convert ice to liquid water is:

$Q = m \times (\Delta h_m + C_{p,H2O} \times \Delta T)$

where $\Delta T = T_{final} - T_{initial}$ = 55 ˚C – 0 ˚C
ΔT = 55 ˚C

So plugging in all the values (make sure to check units so that they cancel out correctly)

Q = (5 kg) x [(333 kJ/kG) + (4.2 kJ/kg ˚C x 55 ˚C)]

Q = 2820 kJ

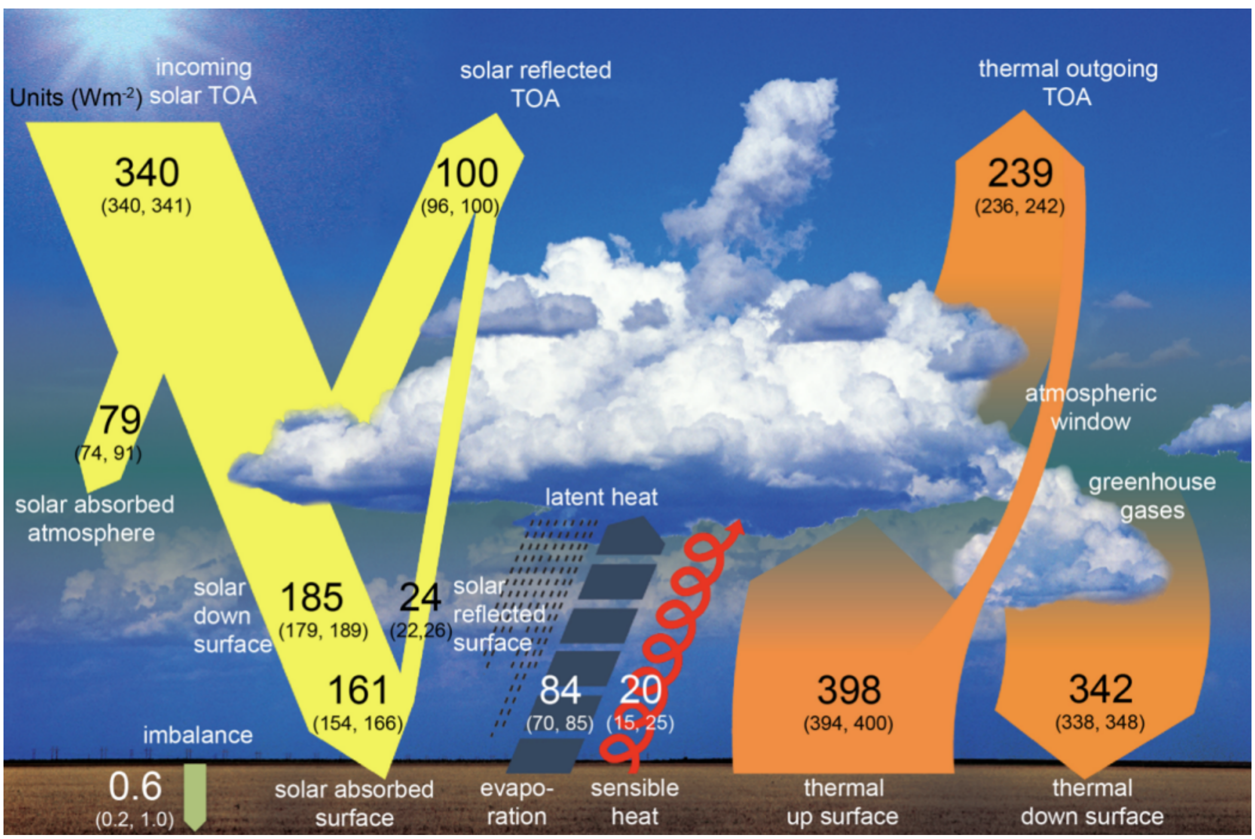
5. Why is it problematic to calculate the mass of the Earth's atmosphere as the product of air density and atmospheric volume? Select all that apply.
   a. Air is a mixture of N2 and O2
   b. Air density varies with altitude
   c. It is difficult to define the height and volume of the atmosphere
   d. Multiplying density by volume does not give a mass

6. Rank each of the constituents of Earth's atmosphere listed below from most abundant (#1) to least abundant (#4).
   - **Argon → 3**
   - **Carbon dioxide → 4**
   - **Nitrogen → 1**
   - **Oxygen →2**

7. Why does the record of measured carbon dioxide concentrations at the summit of Mauna Loa in Hawaii show a seasonal cycle (highest in May and lowest in September)?
    a. Solubility of CO2 in the ocean varies by season due to changes in water temperature
    b. Anthropogenic emissions of CO2 increase in summer
    c. Earth is closer to the sun during summer months
    d. Photosynthetic activity by plants and algae is less vigorous during winter months

8. Which of the following kinds of radiation are emitted by the sun? Select all that apply.
    a. Ultraviolet radiation
    b. Visible light
    c. Infrared radiation

9. From data shown in the figure below, calculate the albedo of the Earth's **surface** (the value for albedo that we discussed in class is for top of atmosphere or TOA conditions). Report your answer as a dimensionless ratio, rounded to the nearest 0.01.



Answer: For this problem, we are only considering the albedo of the Earth's surface (not including cloud effects). Remember, albedo is defined as the fraction of incoming solar radiation that is reflected. From the graphic, the incoming solar radiation that reaches earth's surface is 185 W/m^2 and 24 W/m^2 of that is reflected. Thus, the albedo of earth's surface is:

Albedo = 24/185 = **0.13**

10. Newly-discovered Planet Zog is located at a mean distance of 300 million km from the sun, which is exactly twice the mean earth-sun distance of 150 million km. Estimate the average surface temperature on Zog assuming planetary albedo = 0.10 and neglecting the greenhouse effect. Report your answer in degrees Kelvin (K), rounded to the nearest degree. Enter a numerical answer only, do not include the unit symbol (K) as part of what you enter.

Answer: Similar to HW1 #2, to find the average surface temperature on Zog, we need to first find the solar radiation reaching Zog's atmosphere. To do that, we will use the relation:

$S_{Earth} \times 4\pi \times D^2_{Earth} = S_{Zog} \times 4\pi \times D^2_{Zog}$

where S_{Earth} = incoming solar radiation to Earth in W/m^2 = 1360 W/m^2
D_{Earth} = mean distance between Earth and sun = 150 x 10^6 km = 150 x 10^9 m
S_{Zog} = incoming solar radiation to Zog in W/m^2
D_{Zog} = mean distance between Zog and sun = 300 x 10^6 km = 300 x 10^9 m

To solve for the incoming solar radiation to Zog (make sure to check units):

$$S_{Zog} = \frac{SEarth \times 4\pi \times DEarth^2}{4\pi \times DZog^2} = \frac{(1360\ W/m^2)(4\pi)(150 \times 10^9\ m)^2}{(4\pi)(300 \times 10^9\ m)^2} = 340\ \text{W/m}^2$$

Now that we know S_{Zog}, we can use the planetary energy balance equation (derived in *L04: Planetary Energy Balance*) to find that the surface temperature equation is:

$$T_{Zog} = \sqrt[4]{\frac{Szog\,(1-\alpha)}{4\sigma}} = \sqrt[4]{\frac{(340\ W/m^2)(1-0.1)}{4(5.67 \times 10^{-8}\ W/(m^2\ K^4))}} = \mathbf{190\ K}$$

11. Which of the following are relevant when calculating the global warming potential (GWP) for a specific greenhouse gas? Select all that apply.
    a. **Definition of time horizon used for planning purposes**
    b. Emission rate of the greenhouse gas
    c. **Atmospheric lifetime of the greenhouse gas**
    d. **Infrared absorption properties of the greenhouse gas**

12. In a book titled "The Population Bomb" published in 1968, Ehrlich predicted large increases in the number of people dying in the 1970s. Which of the following was most responsible for preventing this prediction from coming true?
    a. Warmer weather due to climate change
    b. Increased rainfall due to climate change
    c. Increased crop yields due to changes in agricultural practices
    d. Global eradication of malaria and tuberculosis

13. Why does the rate of population change (dP/dt) slow down as P increases in a logistic growth model?
    a. Population growth does not slow down, it continues to grow exponentially
    b. Finite supply of needed nutrients/resources starts to limit population growth
    c. The parameter r in the logistic growth model varies with time
    d. The parameter K in the logistic growth model varies with time

14. World population in the year 2000 was 6.0 billion, with a growth rate (birth rate-death rate) of 1.1% per year in that year. Estimate world population in 2050, assuming a logistic growth law and a carrying capacity of 12 billion. Round your answer to the nearest 0.1 billion people living on the planet as of 2050.

Answer: From *L06: Population Growth*, the equation for logistic growth is:

P(t) = $\frac{K}{1+e^{-rt}(\frac{K}{P0}-1)}$

The tricky part of this problem is that you cannot plug in r0 = 1.1% into the above equation. The r0 given in the problem statement is the growth rate in the year 2000, but we need to back calculate to adjust the growth rate to its "original" value and use that in the equation (see *L06: Population Growth* for more details). To do this, we will use the equation:

$r0 = r(1-\frac{P0}{K})$ where K (carrying capacity) = 12 x 10^9 people
$r0$ (growth rate at t=0) = 1.1 %
P0 (population at t = 0 (2000)) = 6.0 x 10^9 people

$r = \frac{r0}{(1-\frac{P0}{K})} = \frac{1.1\%}{(1-\frac{6\,x\,10^9\,people}{12\,x\,10^9\,people})}$ = 2.2%

Now that we know the growth rate, we want to find the population in 2050, aka when t = 50 years. To do so, we plug in all the information given in the problem and solve for P(t = 50):

P(t = 50 years) = $\frac{12\,x\,10^9\,people}{1+e^{-(0.022)(50years)}(\frac{12\,x\,10^9\,people}{6\,x\,10^9\,people}-1)}$
= 9.0 x 10^9 people
= 9.0 billion people

15. Lithium production is growing at a rate of 5% per year. Assuming unrestricted exponential growth, how long will it take for the lithium production rate to double? Answer in years, rounding your answer to the nearest whole number of years.

Answer:

From *L06: Population Growth*, the equation for exponential growth is:

We know that $P(t) \; = P_0 e^{rt} \; with\, r \; = \; 5\%$

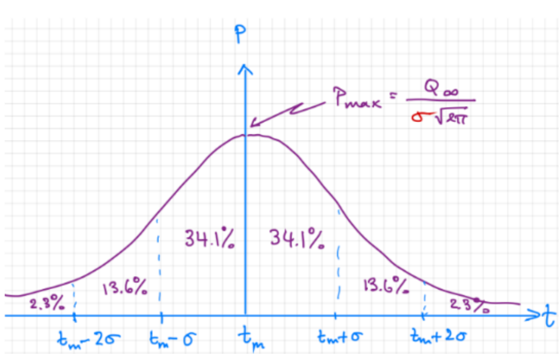
We want to know when $P_1 = P_0 e^{rt} \; = \; 2 \; * \; P_0$

$e^{rt} \; = \; 2$
$t \; = \frac{ln(2)}{r} \; \simeq \; 13.86 \; \simeq$ **14 years**

16. Suppose resource production follows a symmetric production curve and that the year of peak production already happened back in 1990. Assume the standard deviation (a measure of how spread out in time the production is on either side of the peak year), = 16 years. What fraction of the total resource will have been produced by 2022?
    a. 68.2%
    b. 84.1%
    c. 95.4%
    d. 97.7%
    e. 98.6%

Answer: As in HW2, we sum the area below the curve until 2022:

$2022 \; = \; 1990 \; + \; 2 \; * \; 16 \; = t_m \; + \; 2 \; * \; \sigma$



We thus have 100% - 2.3% = **97.7%**

17. Match each of the statements that follow below to the most appropriate fossil fuel (coal, oil, or natural gas)
    a. Causes high emissions of sulfur dioxide, nitrogen oxides, and ash particles when burned → **Coal**
    b. Consists mainly of methane → **Natural gas**
    c. Asia Pacific region is the largest producer and consume→ **Coal**
    d. Middle East region is the largest exporter → **Oil**
    e. Main source of fuel for the transportation sector → **Oil**

18. A fuel with chemical formula C H O has heat of formation Δh = -303 kJ/mol and a molecular weight of 60 g/mol. Calculate the lower heating value (LHV) for this fuel given the following combustion stoichiometry:

$$C_3H_8O + 4.5\ O_2 + 18\ N_2 \text{ ---> } 3\ CO_2 + 4\ H_2O + 18\ N_2$$

The corresponding heats of formation for water vapor and carbon dioxide are -242 and -394 kJ/mol, respectively. Round your answer to the nearest whole number and enter only a numerical value (assumed to be in kJ/g units).

Answer:

From L09 Heating value:

$$\Delta h_{combustion} = 3 * \Delta h_{H20} + 4 * \Delta h_{CO2} - \Delta h_{C3H8O}$$

$$LHV = \frac{\Delta h_{combustion}}{MW} = 30,8 \simeq \mathbf{31\ kJ/g}$$

19. As discussed in the assigned reading from HW2, which of the following elements are part of the least-cost pathway to net-zero CO2 emissions in the US by 2050? Select all that apply.
    a. Decarbonize electric power generation
    b. Increase end use energy efficiency
    c. Carbon capture and storage
    d. Electrification of residential heating and transportation sectors
20. Match each listed source of electric power to a corresponding statement about its future status assuming we achieve net-zero CO2 emissions in the US by 2050, assuming we follow the least-cost central case pathway
    a. Wind power → **Increase installed capacity**
    b. Solar power → **Increase installed capacity**
    c. Natural gas-fired power plants → **Retain existing capacity**
    d. Coal-fired power plants → **Phase out completely**