Worksheet 3: Gibb's Free Energy, Light, Frequency, Wavelength, etc.

Helpful information for this worksheet:

Substance	ΔH_f^o (kJ/mole)	S° (J/mole·K)	ΔG_f^o (kJ/mole)
C (s, graphite)	?	5.686	?
CO (g)	-110.5	197.5	-137.2
CO_2 (g)	-393.5	213.7	-394.4
C_3H_8 (g)	-105	269.9	-24.5
H_2 (g)	?	130.6	?
H_2O (l)	-285.840	69.940	-237.192
H_2O (g)	-241.826	188.72	-228.60
N_2 (g)	?	191.5	?
NO (g)	90.29	210.65	86.60
NO_2 (g)	33.2	239.9	51
N_2O_4 (g)	9.16	304.3	97.7
O_2 (g)	?	205.0	?

Concept questions: 17.43
Gibb's Free Energy: 17.39, 17.41, 17.55, 17.57, 17.59, 17.61, 17.89
Light, frequency, wavelength, energy: 7.41, 7.43, 7.45, 7.47, 7.75, 7.93
Photoelectric effect: 7.87, 7.99

1. A mixture of CO and H_2 is produced by passing steam over charcoal. Calculate the $\Delta G°$ value for the reaction and predict the lowest temperature at which the reaction is spontaneous.

   $$H_2O\ (g) + C\ (s, \text{graphite}) \rightarrow H_2\ (g) + CO\ (g)$$

2. Calculate the $\Delta G°$ values for the following atmospheric reactions, which contribute to the formation of chemical smog
   a. $N_2\ (g) + O_2\ (g) \rightarrow 2\ NO\ (g)$
   b. $2\ NO\ (g) + O_2\ (g) \rightarrow 2\ NO_2\ (g)$
   c. $NO\ (g) + ½\ O_2\ (g) \rightarrow NO_2\ (g)$
   d. $2\ NO_2\ (g) \rightarrow N_2O_4\ (g)$
3. Which of the reactions in question #2 are spontaneous at:
   a. high temperature?
   b. low temperature?
   c. all temperatures?
4. Given the following:
   $C_3H_8\ (g) + 5\ O_2\ (g) \rightarrow 3\ CO_2\ (g) + 4\ H_2O\ (l)$ $\Delta H° = -2220$ kJ
   a. Without using data from the Table, predict whether $\Delta G°$ for this reaction is more negative or less negative than $\Delta H°$.
   b. Using data from the Table, calculate the standard free energy change for the reaction at 298 K
5. For a particular reaction, $\Delta H = -32$ kJ and $\Delta S = -98$ J/K. Assume that ΔH and ΔS do not vary with temperature.
   a. At what temperature will the reaction switch from spontaneous to non-spontaneous or vice versa?

   b. If the temperature is increased from that in part (a), will the reaction be spontaneous or nonspontaneous?
6. The energy required to remove the electron from a hydrogen atom is 2.18 x 10^{-18} J. What is the wavelength of a photon of this radiation with this much energy
7. The light blue glow given off by mercury streetlamps has a wavelength of 436 nm. What is the frequency in hertz?
8. What is the wavelength (in meters) of an FM radio wave with frequency of 102.5 MHz?
9. What is the frequency of a radar wave with a wavelength of 10.3 cm?
10. Which has the higher frequency, red light or violet light? Which has the longer wavelength? Which has the greater energy?
11. Without calculating anything, decide when member of each pair has the higher energy and then calculate the energies for the following values (in kilojoules per mole).
    a. An FM radio wave at 99.5 MHz and an AM radio wave at 1150 kHz
    b. An X ray with a wavelength of 3.44 nm and a microwave with a wavelength of 6.71 cm
    c. Light with a wavelength of 10 μm and light with a wavelength of 1000 pm.
12. What is the wavelength (in meters) of photons with the following energies?
    a. 90.5 kJ/mole
    b. 8.05 x 10^{-4} kJ/mole
    c. 1.83 x 10^{3} kJ/mole
13. The workfunction of silver is 7.59 x 10^{-19} J. What is the longest wavelength of EM radiation that can eject an electron from the surface of a piece of silver?
14. Solar energy can be converted into electricity with the use of the photoelectric effect. Could tantalum (Φ = 6.41 x 10^{-19} J) be used to construct such solar-powered photocells? Assume that most of the electromagnetic radiation energy from the sun is in the visible region near 500 nm.
15. Could tungsten (Φ = 7.16 x 10^{-19} J) be used to construct solar-powered photocells?
16. When a piece of metal is irradiated with UV radiation (λ = 162 nm), electrons are ejected with a kinetic energy of 5.34 x 10^{-19} J. What is the work function of the metal?
17. Thin layers of potassium (Φ = 3.68 x 10^{-19} J) and sodium (Φ = 4.41 x 10^{-19} J) are exposed to radiation of wavelength 300 nm. Which metal emits electrons with the greater velocity? What is the velocity of these electrons?

Key:

1. $\Delta G°$ = 91.4 kJ; T = 981 K
2. a. +173.2 kJ b -70.6 kJ c. -35.3 kJ d. -4.8 kJ
3. a. a b. b, c, and d c. none
4. Less negative, -2107 kJ
5. 330 K, nonspontaneous
6. 9.11 x 10^{-8} m or 91.1 nm
7. 6.88 x 10^{14} Hz

8. 2.93 m
9. 2.91×10^{9} Hz
10. violet, red, violet
11. a. FM more E; FM wave, 3.97×10^{-5} kJ/mole, AM wave, 4.589×10^{-7} kJ/mole,
    b. x ray more E; X ray, 3.48×10^{4} kJ/mole, microwave, 1.78×10^{-3} kJ/mole,
    c. pm more E; μm, 12 kJ/mole, pm, 1.2×10^{5} kJ/mole
12. a. 1.32×10^{-6} m, near IR, b. 0.149 m, radio wave c. 6.54×10^{-8} m, UV
13. 262 nm
14. No
15. No
16. 6.96×10^{-19} J
17. K, 8.03×10^{5} m/s for K, 6.97×10^{5} m/s for Na