Names ____________________________  School ____________________________
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Chemistry Lab Test

created by kenniky

KEY

note to graders: calculation errors (if all the work is there) is a 1 pt deduction
Part I. Thermodynamics [60 pt]

1. What are the four laws of thermodynamics? (6 pt) [1.5 pt each]

   (0) If two systems are in thermal equilibrium with a third, they are in thermal equilibrium with each other

   (1) energy cannot be created or destroyed

   (2) entropy increases

   (3) entropy approaches constancy as temperature approaches absolute 0

2. A spherical balloon 30.0 cm in diameter is expanded until its diameter is 40.0 cm. If the pressure on the balloon is 1.00 atm, how much work was done on the balloon? (5 pt)

   \[ W = -P \Delta V \]

   \[ V_f = \frac{4}{3} \pi (20.0)^3 = 33500 \text{ cm}^3 \] 

   \[ V_i = \frac{4}{3} \pi (15.0)^3 = 14100 \text{ cm}^3 \] 

   \[ W = -(1.00 \text{ atm})(33500 - 14100) \text{ cm}^3 = -19400 \text{ atm cm}^3 \]

   1 pt for each of the volumes [half credit if didn’t convert into radius], 3 pt for \( W = -P \Delta V \)

3. What is \( \Delta H \) for the system in question 2 if \( \Delta E \) is +4.00 J? (1 atm cm\(^3\) = 0.1 J) (3 pt)

   \[ \Delta H = \Delta E + P \Delta V = \Delta E - W = 4.00 \text{ J} - (-19400 \text{ atm cm}^3 \cdot \frac{0.1 \text{ J}}{\text{ atm cm}^3}) = 1944 \text{ J} \]

4. From questions 2 and 3, is the system endothermic or exothermic? (1 pt)

   endothermic

5. Find \( \Delta H^\circ \) for the reaction

   \[ 2\text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{g}) \rightarrow \text{C}_2\text{H}_2(\text{g}) + 5/2 \text{O}_2(\text{g}), \]

   given the following reactions and subsequent \( \Delta H^\circ \) values:

   (1) \[ \text{C}_2\text{H}_2(\text{g}) + 2\text{H}_2(\text{g}) \rightarrow \text{C}_2\text{H}_6(\text{g}) \quad \Delta H = -94.5 \text{ kJ} \]

   (2) \[ \text{H}_2\text{O}(\text{g}) \rightarrow \text{H}_2(\text{g}) + \frac{1}{2} \text{O}_2(\text{g}) \quad \Delta H = +71.2 \text{ kJ} \]

   (3) \[ \text{C}_2\text{H}_6(\text{g}) + 7/2 \text{O}_2(\text{g}) \rightarrow 2\text{CO}_2(\text{g}) + 3\text{H}_2\text{O}(\text{g}) \quad \Delta H = -283 \text{ kJ} \] (4 pt)

   \[-(3) - 2(2) - (1) = 283 \text{ kJ} - 142.4 \text{ kJ} + 94.5 \text{ kJ} = 235.9 \text{ kJ} \]
6. For a particular reaction, $\Delta H = +145 \text{ kJ/mol}$. If the temperature is 273 K, for what values of $\Delta S$ is the reaction spontaneous? (3 pt)

$$
\Delta H - T \Delta S = \Delta G < 0 \quad [2 \text{ pt}] \\
145 \text{ kJ/mol} - 273K \Delta S < 0 \quad [1 \text{ pt for substituting these in]}
$$

273K $\Delta S > + 0.531 \text{ kJ/mol K}$

-1 pt if they didn’t switch the inequality

7. A 10.00 mL container of water is at 10.0 °C. A 2.23 g piece of zinc at 121 °C is dropped into the container. What is the final temperature of the system? ($c_{\text{zn}} = 0.384 \text{ J/g °C}$) (5 pt)

$$10.00mL \cdot \frac{1g}{mL} \cdot 4.184 \frac{J}{g \text{ °C}} (T - 10.0^\circ \text{C}) = 2.23g \cdot 0.384 \frac{J}{g \text{ °C}} (121^\circ \text{C} - T)$$

$$T = 12.2^\circ \text{C}$$

8. After the temperature of the system in question 7 has settled, the zinc is removed and heated to 98.6 °C along with a 0.441 g piece of titanium. Both metals are then released back into the water simultaneously. What is the final temperature of this new system? ($c_{\text{ti}} = 0.523 \text{ J/g °C}$) (8 pt)

$$10.00 \text{ mL} \cdot \frac{1g}{mL} \cdot 4.184 \frac{J}{g \text{ °C}} (T - 12.2^\circ \text{C}) = 2.23g \cdot 0.384 \frac{J}{g \text{ °C}} (98.6^\circ \text{C} - T) + 0.441g \cdot 0.523 \frac{J}{g \text{ °C}} (98.6^\circ \text{C} - T)$$

$$T = 14.4^\circ \text{C}$$

-1 pt if they used 10.0°C instead of 12.2°C. -3 pt if they put any of the values on the wrong side of the equals sign (i.e. used $\Delta E_{\text{water}} + \Delta E_{\text{zn}} = \Delta E_{\text{ti}}$ or something similar)

9. At 273 K, the reaction

$$\text{A (aq)} \Leftrightarrow 2\text{B (aq)}$$

has an equilibrium constant of 375. What is $\Delta G^o$ for the reaction? (4 pt)

$$\Delta G^o = -RT \ln K = -8.3145 \frac{J}{molK} \cdot 273K \cdot \ln 375$$

$$\Delta G^o = - 13500 \frac{J}{mol} = -13.5 \frac{kJ}{mol}$$

-1 pt if they use the wrong value for $R$

10. At 298 K, the equilibrium constant of the reaction in question 9 is 525. What are $\Delta H^o$ and $\Delta S^o$ for the reaction? (6 pt)

$$ln \frac{K}{K_1} = \frac{\Delta H^o}{RT} (\frac{1}{T_1} - \frac{1}{T})$$

$$ln \frac{K}{K_1} = \frac{8.3145 \frac{J}{molK}}{273K} (\frac{1}{298K} - \frac{1}{273K})$$

$$\Delta H^o = -9160 \frac{J}{mol} = -9.16 \frac{kJ}{mol}$$

$$\Delta G^o = \Delta H^o - T \Delta S^o$$

$$-13.5 \frac{kJ}{mol} = -9.16 \frac{kJ}{mol} - 273K \Delta S^o$$

$$\Delta S^o = +0.0157 \frac{kJ}{molK} = +15.7 \frac{kJ}{molK}$$

[3 pt]
11. The reaction in question 9 is in equilibrium when half the amount of existing B is removed from the system. If the temperature is 400.0 K, what is ΔG? (7 pt)

\[
\ln K = \frac{-\Delta H^\circ}{R} \left(\frac{1}{T}\right) + \frac{\Delta S^\circ}{R} = \frac{-9160 \text{ J/mol}}{8.3145 \text{ mol/K}} \left(\frac{1}{400 \text{ K}}\right) + \frac{15.7 \text{ J/K mol}}{8.3145 \text{ mol/K}} \Rightarrow K = 104.3 \quad [2 \text{ pt}]
\]

\[104.3 = \frac{[B]_{eq}^2}{[A]_{eq}} \quad Q = \frac{([B]_{eq}/2)^2}{[A]_{eq}} = \frac{K}{4} = 26.1 \quad [2 \text{ pt}]
\]

\[\Delta G = \Delta G^\circ + RT \ln Q = -13500 \frac{J}{\text{mol}} + 8.3145 \frac{J}{\text{mol K}} \cdot 400 \text{ K} \ln 26.1 = -2615 \frac{J}{\text{mol}} = -2.615 \frac{kJ}{\text{mol}} \quad [3 \text{ pt}]
\]

12. You have a 1.00 mol sample of water at -30.0 °C and you heat it until you have gaseous water at 140.0 °C. Calculate q for the entire process. Use the following data:

\[c_{\text{ice}} = 2.03 \text{ J/g °C}
\]
\[c_{\text{water}} = 4.18 \text{ J/g °C}
\]
\[c_{\text{steam}} = 2.02 \text{ J/g °C}
\]
\[\text{H}_2\text{O (s)} \rightarrow \text{H}_2\text{O (l)} \quad \Delta H_{\text{fusion}} = 6.02 \text{ kJ/mol}
\]
\[\text{H}_2\text{O (l)} \rightarrow \text{H}_2\text{O (g)} \quad \Delta H_{\text{vaporization}} = 40.7 \text{ kJ/mol}
\]

\[q = 1.00\text{mol} \cdot \frac{18.015 g}{\text{mol}} \cdot \frac{2.03 \text{ J}}{\text{g °C}} \left(0 - (-30.0 °C)\right) \frac{kJ}{1000J} + 1.00\text{mol} \cdot 6.02 \frac{kJ}{\text{mol}} + 1.00\text{mol} \cdot \frac{18.015 g}{\text{mol}} \cdot \frac{4.18 \text{ J}}{\text{g °C}} \left(100 - 0 °C\right) \frac{kJ}{1000J}
\]
\[+ 1.00\text{mol} \cdot 40.7 \frac{kJ}{\text{mol}} + 1.00\text{mol} \cdot \frac{18.015 g}{\text{mol}} \cdot \frac{2.02 \text{ J}}{\text{g °C}} \left(140 - 100 °C\right) \frac{kJ}{1000J}
\]

\[= 56.8 \text{ kJ} \quad [1 \text{ pt for each of the different energy parts}]
\]

13. Above is my expertly drawn phase diagram. Label the three regions with the appropriate phase (solid, liquid, or gas), and below name and define the points X and Y. (5 pt) 1 pt per item

left: solid, top right: liquid, bottom right: gas

X: triple point, all three phases coexist

Y: critical point, only supercritical fluid exists beyond this temperature
Part II. Physical Properties [50 pt]

1. At what temperature is water the most dense? (2 pt)

   4°C

2. Which two elements are liquid at room temperature? (2 pt)

   Mercury and bromine (1 pt each)

3. Graphite and diamond are both made of pure carbon; however, graphite is very soft while diamond is one of the hardest substances known. Explain. (4 pt)

   Graphite is in layers: the layers do not have very strong bonds between them so graphite can separate into several layers

   Diamond is a lattice and has no “weak points” (2 pt each)

4. Explain the difference between an intensive and an extensive property, and give an example of each. (3 pt)

   Intensive: doesn’t depend on how much there is. Density, hardness, color, melting/boiling point, specific heat capacity, etc
   Extensive: does depend on how much there is. Mass, volume, energy, enthalpy, entropy, etc.
   (1 pt for each explanation, 0.5 pt for each example)

5. Why is salt soluble in water, but sugar not? (4 pt)

   Salt is a polar molecule. Water is also polar, so they attract to one another and the salt is suspended in the water

   Sugar is not polar so this doesn’t happen

   (2 pt for each)
6. You are given samples of two unknown liquids, A and B. Create a quantifiable experiment to determine their relative viscosities. (4 pt)

Possible answers:
- fill graduated cylinder → put ball bearing in → see how long it takes to sink
- pour at one end of a container → see how long it takes to spread a certain distance

7. In the event Bungee Drop, a weight, attached to an elastic cord, is dropped from a certain height. Say a 10 m cord with a 3 cm circumference is used with a 400 g weight. After the weight is released, it hangs 10.01 m below the release point. If a 600 g weight was used instead, how low would it hang? (7 pt)

Cross-sectional area: 
\[ 2\pi r = 3 \Rightarrow r = \frac{3}{2\pi} \quad A = \pi r^2 = \pi \left(\frac{3}{2\pi}\right)^2 = \frac{9}{4\pi} \approx 0.716 \text{ cm}^2 \]

Stress:
\[ \text{stress} = \frac{4000N}{(0.716 \text{ cm}^2)(100\text{ cm/m})^2} = 0.559 \text{ N/m}^2 \]

Strain:
\[ \text{strain} = \frac{0.01 \text{ m}}{10 \text{ m}} = 0.001 \]

Young’s modulus:
\[ \text{Young’s modulus} = \text{stress} / \text{strain} = 559 \text{ N/m}^2 \]

New stress:
\[ \text{new stress} = \frac{6000N}{(0.716 \text{ cm}^2)(100\text{ cm/m})^2} = 0.838 \text{ N/m}^2 \]

Young’s modulus:
\[ \text{Young’s modulus} = \frac{0.838}{(\Delta x / 10)} = 559 \quad \Rightarrow \quad \Delta x = 0.0150 \text{ m} \]

\[ 10 + 0.0150 = 10.015 \text{ m} \]
8. On the blank periodic table below, use the letters below to mark where the elements are that have:

(8 pt) 2 pt each
A. the largest atomic radius  bottom left
B. the highest ionization energy  top right
C. the highest electron affinity  top right
D. the largest molar mass  bottom right (2 pt each)

9. Explain why each of the trends that you described above exists. (16 pt) 4 pt each
   a. Atomic radius
   bottom: more electron layers → larger
   left: less protons → less attraction on electrons → electrons further out

   b. Ionization energy
   the elements at the top right are small, so the protons exert more attractive force on the outermost electrons. Additionally, the elements at the top right have full or close to full energy layers so removing an electron would be bad

   c. Electron affinity
   Similar reason to ionization energy: small → can pull electrons from farther away (relative to its outer electron layer) and wants full energy level so tries to get electrons

   d. Molar mass
   things at bottom right have more protons and need more neutrons to stop their nuclei from exploding