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)

$W = -P\Delta V \qquad V_f = \frac{4}{3}\pi(20.0)^3 = 33500\ cm^3 \qquad V_i = \frac{4}{3}\pi(15.0)^3 = 14100\ cm^3$

$W = -(1.00\ atm)(33500 - 14100)\ cm^3 = -19400\ atm\ cm^3$

1 pt for each of the volumes [half credit if didn't convert into radius], 3 pt for W = -PΔV

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

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

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

endothermic

5. Find ΔH° for the reaction

$$2CO_2\ (g) + H_2O\ (g) \rightarrow C_2H_2\ (g) + 5/2\ O_2\ (g),$$

given the following reactions and subsequent ΔH° values:

(1)	$C_2H_2\ (g) + 2H_2\ (g) \rightarrow C_2H_6\ (g)$	ΔH = -94.5 kJ	
(2)	$H_2O\ (g) \rightarrow H_2\ (g) + ½\ O_2\ (g)$	ΔH = +71.2 kJ	
(3)	$C_2H_6\ (g) + 7/2\ O_2\ (g) \rightarrow 2CO_2\ (g) + 3H_2O\ (g)$	ΔH = -283 kJ	(4 pt)

- (3) - 2 (2) - (1) = 283 kJ - 142.4 kJ + 94.5 kJ = 235.9 kJ

6. For a particular reaction, ΔH = +145 kJ/mol. If the temperature is 273 K, for what values of ΔS is the reaction spontaneous? (3 pt)

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

$273K\ \Delta S > 145\ kJ/mol$ $\Delta S > +0.531\ kJ/mol\ K$

-1 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_{Zn} = 0.384 J/g °C) (5 pt)

$$10.00mL \cdot \frac{1g}{mL} \cdot 4.184\frac{J}{g\,^oC}(T - 10.0^oC) = 2.23g \cdot 0.384\frac{J}{g\,^oC}(121^oC - T)$$

$T = 12.2^oC$

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_{Ti} = 0.523 J/g °C) (8 pt)

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

(water) (zinc) (titanium)

T = 14.4°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 $\Delta E_{water} + \Delta E_{zinc} = \Delta E_{titanium}$ or something similar)

9. At 273 K, the reaction

A (aq) ⇔ 2B (aq)

has an equilibrium constant of 375. What is ΔG° for the reaction? (4 pt)

$\Delta G^o = -RT\ ln\ K = -8.3145\frac{J}{mol\ K} \cdot 273K \cdot ln\ 375$ -1 if they use the wrong value for R

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

10. At 298 K, the equilibrium constant of the reaction in question 9 is 525. What are ΔH° and ΔS° for the reaction? (6 pt)

$ln\frac{K_2}{K_1} = \frac{-\Delta H^o}{R}(\frac{1}{T_1} - \frac{1}{T_2})$ $ln\frac{525}{375} = \frac{-\Delta H^o}{8.3145\frac{J}{mol\ K}}(\frac{1}{273\ K} - \frac{1}{298\ K})$ $\Delta H^o = -9160\frac{J}{mol} = -9.16\frac{kJ}{mol}$ [3 pt]

$\Delta G^o = \Delta H^o - T\Delta S^o$ $-13.5\frac{kJ}{mol} = -9.16\frac{kJ}{mol} - 273K\ \Delta S^o$ $\Delta S^o = +0.0157\frac{kJ}{mol\ K} = +15.7\frac{J}{mol\ K}$ [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)

$ln\ K = \frac{-\Delta H^o}{R}(\frac{1}{T}) + \frac{\Delta S^o}{R} = \frac{-9160\frac{J}{mol}}{8.3145\frac{J}{mol\ K}}(\frac{1}{400\ K}) + \frac{15.7\frac{J}{mol\ K}}{8.3145\frac{J}{mol\ K}} \Rightarrow K = 104.3$ [2 pt]

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

$\Delta G = \Delta G^o + RT\ ln\ Q = -13500\frac{J}{mol} + 8.3145\frac{J}{mol\ K} \cdot 400K\ ln\ 26.1 = -2615\frac{J}{mol} = -2.615\frac{kJ}{mol}$ [3 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:

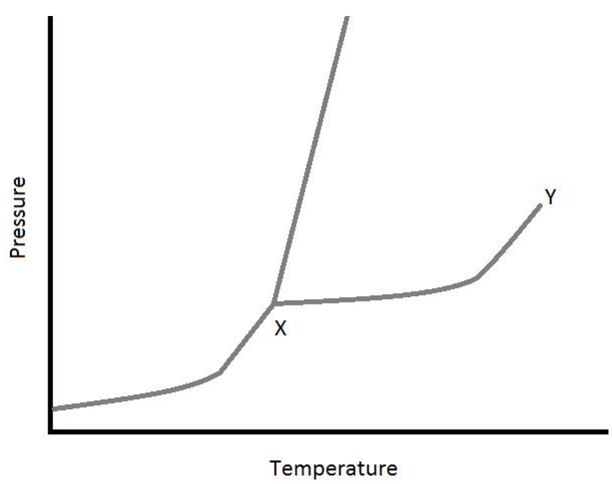
c_{ice}	2.03 J/g °C
c_{water}	4.18 J/g °C
c_{steam}	2.02 J/g °C
H_2O (s) → H_2O (l)	ΔH_{fusion} = 6.02 kJ/mol
H_2O (l) → H_2O (g)	$\Delta H_{vaporization}$ = 40.7 kJ/mol

(5 pt)

$q = 1.00mol\frac{18.015g}{mol} \cdot \frac{2.03J}{g\ ^oC}(0-(-30.0^oC))\frac{1kJ}{1000J} + 1.00mol \cdot 6.02\frac{kJ}{mol} + 1.00mol\frac{18.015g}{mol} \cdot \frac{4.18J}{g\ ^oC}(100-0^oC)\frac{1kJ}{1000J}$

$+ 1.00mol \cdot 40.7\frac{kJ}{mol} + 1.00mol\frac{18.015g}{mol} \cdot \frac{2.02J}{g\ ^oC}(140-100^oC)\frac{1kJ}{1000J}$

$= 56.8\ kJ$ [1 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)

   4ºC

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: $2\pi r = 3 \Rightarrow r = \frac{3}{2\pi}$ $A = \pi r^2 = \pi(\frac{3}{2\pi})^2 = \frac{9}{4\pi} \approx 0.716\ cm^2$ [1 pt]

stress = $4000N/(0.716\ cm^2 * (100cm/m)^2) = 0.559\ N/m^2$ [1 pt]

strain = 0.01 m / 10 m = 0.001 [1 pt]

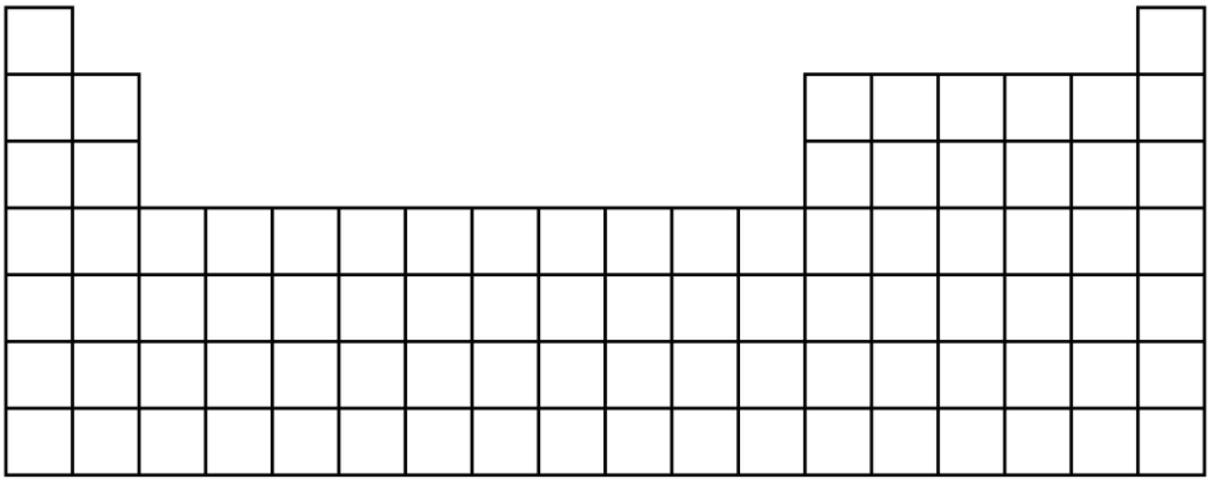
Young's modulus = stress / strain = 559 N/m^2 [1 pt]

new stress = 6000N/(0.716 cm^2 * (100cm / m)^2) = 0.838 N/m^2 [1 pt]

Ym = 0.838 / (Δx / 10) = 559 ⇒ Δx = 0.0150 m [1 pt]

10 + 0.0150 = 10.015 m [1 pt]

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