Exam 1 - S23 - McCord - ch302

last name ____________ first name ____________ signature ____________________

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H 1.008																	2 He 4.003
3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.38	31 Ga 69.72	32 Ge 72.64	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
55 Cs 132.91	56 Ba 137.33	57 La 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.20	83 Bi 208.98	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 Ac (227)	104 Rf (267)	105 Db (268)	106 Sg (269)	107 Bh (270)	108 Hs (270)	109 Mt (278)	110 Ds (281)	111 Rg (282)	112 Cn (285)	113 Nh (286)	114 Fl (289)	115 Mc (290)	116 Lv (293)	117 Ts (294)	118 Og (294)

58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97
90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (266)

constants

$R = 0.08206$ L atm/mol K

$R = 0.08314$ L bar/mol K

$R = 62.36$ L Torr/mol K

$R = 8.314$ L kPa/mol K

$R = 8.314$ J/mol K

$N_A = 6.022 \times 10^{23}$ /mol

conversions

1 atm = 760 torr

1 atm = 14.7 psi

1 atm = 101325 Pa

1 atm = 1.01325 bar

1 bar = 10^5 Pa

°F = °C(1.8) + 32

K = °C + 273.15

conversions

1 in = 2.54 cm

1 ft = 12 in

1 yd = 3 ft

1 mi = 5280 ft

1 lb = 453.6 g

1 ton = 2000 lbs

1 tonne = 1000 kg

1 gal = 3.785 L

1 gal = 231 in^3

1 gal = 128 fl oz

1 fl oz = 29.57 mL

1 Troy oz = 31.104 g

water data

$C_{s,ice} = 2.09$ J/g °C

$C_{s,water} = 4.184$ J/g °C

$C_{s,steam} = 2.03$ J/g °C

$\rho_{water} = 1.00$ g/mL

$\rho_{ice} = 0.9167$ g/mL

$\rho_{seawater} = 1.024$ g/mL

$\Delta H_{fus} = 334$ J/g

$\Delta H_{vap} = 2260$ J/g

$k_f = 1.86$ °C/m

$k_b = 0.512$ °C/m

$K_w = 1.0 \times 10^{-14}$

This exam should have exactly 25 questions. Each question is equally weighted at 4 points each. You will enter your answer choices on the virtual bubblehseet after you have finished. Your score is based on what you submit on the virtual bubblesheet and not what is circled on the exam.

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1. Rank the following chemicals in terms of increasing miscibility in water (H_2O): heptane (C_7H_{16}), butanol (C_4H_9OH), butyraldehyde ($CH_3(CH_2)_2CHO$), and chlorobutane (C_4H_9Cl).

●a. heptane < chlorobutane < butyraldehyde < butanol

b. butanol < butyraldehyde < chlorobutane < heptane

c. heptane < butyraldehyde < chlorobutane < butanol

d. heptane < butanol < chlorobutane < butyraldehyde

e. chlorobutane < heptane < butyraldehyde < butanol

Explanation: Remember, like dissolves like. The most similar solvent to water is butanol, with its ability to hydrogen bond. Next is butyraldehyde, with its polar C=O bond. Chlorobutane is slightly polar, but little is likely to dissolve in water. Heptane is very non-polar and will mix increadibly poorly with water. Thus, the order is heptane < chlorobutane < butyraldehyde < butanol.

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2. How much heat must be removed (you are cooling here) to cool a 60 g sample of steam at 150 °C to liquid water at 40 °C?

a. 127.5 kJ

b. 191.3 kJ

c. 141.6 kJ

●d. 156.7 kJ

e. 166.8 kJ

Explanation: $\Delta H = mc_{\text{steam}}\Delta T + m\Delta H_{\text{vap}} + mc_{\text{water}}\Delta T = -(60)(2.03)(50) - (60)(2260) - (60)(4.184)(60) = -156.7$ kJ

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3. The Haber-Bosch process generates ammonia by the following reaction:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad K_p = 1.45 \times 10^{-5}$$

at 500°C Now, calculate the equilibrium constant for this reaction:

$$4NH_3(g) \rightleftharpoons 2N_2(g) + 6H_2(g)$$

a. $K_p = 1.37 \times 10^5$

b. $K_p = 1.45 \times 10^{-5}$

c. $K_p = 7.22 \times 10^3$

●d. $K_p = 4.76 \times 10^9$

e. $K_p = 6.90 \times 10^4$

f. $K_p = 5.18 \times 10^7$

Explanation: We have taken the reaction, flipped it, and doubled it. Thus, $K_{\text{new}} = 1/K_{\text{old}}^2$.

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4. Consider the reaction

$$A + 2B \rightleftharpoons 2C + D \qquad K = 9.2 \times 10^3$$

If the concentraion of A is tripled, what will happen to the value of K?

a. K increases because the reaction will shift toward the product side to relieve the stress.

b. K decreases by one-ninth.

c. K decreases by one-third.

d. K increases by a factor of three.

●e. K does not change.

f. K increases by a factor of nine.

Explanation: For any given reaction at a given temperature, K is, by definition, a constant.

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5. Mojo Jojo, archenemy of the Powerpuff Girls, gives you some of the coveted Chemical X. Intrigued, you measure the boiling point here in Austin (local air pressure = 1.0 atm) and find it to be 77°C. You then take a plane to Nepal and miraculously climb Mount Everest to its summit. At an elevation of 8848 m (local air pressure = 0.33 atm) you measure the boiling point and find it to be 44°C. What is the enthalpy of vaporization for Chemical X?

• a. 31.0 kJ/mol

b. 52.5 kJ/mol

c. 3.73 kJ/mol

d. 0.938 kJ/mol

e. 946 kJ/mol

f. 306 kJ/mol

Explanation: Use the Claussius-Clapeyron equation. Let P_1 and T_1 represent one set of measurments, such as those in Austin. Let P_2 and T_2 represent the other measurements, in Nepal. Be sure that T is in Kelvin. Solve for ΔH_{vap}, which will be a positive value because a substance must absorb energy in order to change phase to vapor.

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6. You are the proud owner of a classic 1969 Chevy Camaro. On a particularly cold morning (0°C) you are unable to start your car, so you decide to spray some starting fluid into the carburetor. Success, your car starts! The bottle states that the starting fluid is 1 part diethyl ether (mw = 74.1 g/mol) to 1 part heptane (mw = 100.2 g/mol) by mass. Now, calculate the partial pressure of diethyl ether vapor assuming P°_{ether} = 185 Torr at 0 °C.

• a. 106 Torr

b. 185 Torr

c. 211 Torr

d. 80 Torr

e. 124 Torr

Explanation: This is a Raoult's law problem. $P_{\text{ether}} = \chi_{\text{ether}} P^{\circ}_{\text{ether}}$. We need to find χ_{ether}. 1 part to 1 part by mass just means you use the exact same masses for each of the two fuels for the starting fluid. Let's pick 100.2 g for each of the two. Convert that mass into moles of each. $n_{\text{ether}} = 100.2/74.1 = 1.35$ mol ether. $n_{\text{heptane}} = 100.2/100.2 = 1.00$ mol heptane (see why I picked 100.2 g now?). $\chi_{\text{ether}} = 1.35/(1.35+1.00) = 0.574$. $P_{\text{ether}} = (0.574)(185 \text{ Torr}) = 106$ Torr.

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7. You add some sodium hydroxide pellets into a beaker of room temperature water and stir it until it dissolves. You then attempt to pick up the beaker and find that it is too hot to comfortably handle. Which of the following answer choices regarding the enthalpy of dissolution are consistent with this observation?

a. $\Delta H_{\text{lattice}}$ = +890 kJ; $\Delta H_{\text{solvation}}$ = -889 kJ

• b. $\Delta H_{\text{lattice}}$ = +890 kJ; $\Delta H_{\text{solvation}}$ = -930 kJ

c. It is impossible to say without knowing what $\Delta S_{\text{solution}}$ is.

d. $\Delta H_{\text{lattice}}$ = +890 kJ; $\Delta H_{\text{solvation}}$ = -890 kJ

e. $\Delta H_{\text{lattice}}$ = +930 kJ; $\Delta H_{\text{solvation}}$ = -890 kJ

Explanation: The problem statement implies that the dissolution of sodium hydroxide is exothermic. Thus, $\Delta H_{\text{solvation}}$ is greater in magnitude than $\Delta H_{\text{lattice}}$.

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8. Rank the following chemicals in order of increasing vapor pressure: acetone $(CH_3)_2CO$, isopropanol $(CH_3)_2CHOH$, isobutane $(CH_3)_3CH$, dimethyl ether CH_3OCH_3

a. dimethyl ether < acetone < isopropanol < isobutane

b. isobutane < dimethyl ether < acetone < isopropanol

c. isopropanol < dimethyl ether < acetone < isobutane

d. acetone < isopropanol < dimethyl ether < isobutane

• e. isopropanol < acetone < dimethyl ether < isobutane

Explanation: Identify the strongest IMFs for each molecule. Acetone (highly polar, strong dipole-dipole), isopropanol (H-bonding), isobutane (London dispersion), dimethyl ether (weakly polar, weak dipole-dipole). Based on this information, we would expect isopropanol to be least volatile (H-bonding is the strongest IMF present). Acetone is more polar than dimethyl ether, thus acetone will be less volatile. Isobutane only possesses London dispersion forces, the weakest of all IMFs, thus it will be the most volatile.

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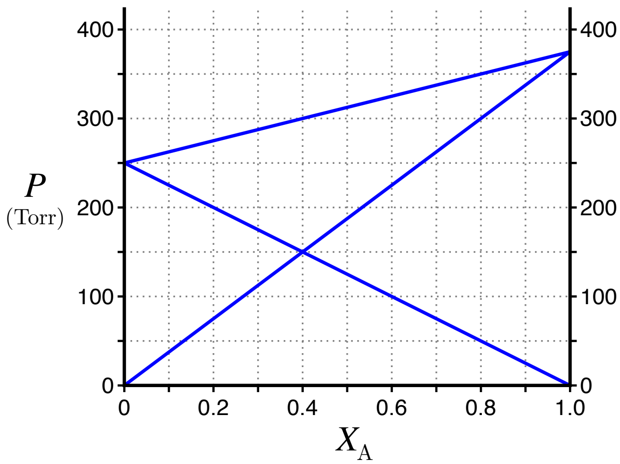
9. Consider the following vapor pressure diagram for a binary liquid of A and B:



The number of moles of A and B are adjusted such that the vapor pressure of A and B are exactly the same pressure. Which of the following mixes will satisfy this condition?

●a. 2 mol A + 3 mol B

b. 1 mol A + 1 mol B

c. 2 mol A + 1 mol B

d. 3 mol A + 2 mol B

e. 1 mol A + 2 mol B

Explanation: The only point on the diagram where the vapor pressure of A and B match is at 150 Torr (the intersection of the two lines). This is 0.4 mole fraction of A and therefore 0.6 mole fraction of B. That is a 2 to 3 ratio of A to B.

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10. Steam reforming converts methane into the industrially useful 'syngas' by the following reaction:

$$CH_4(g) + H_2O(g) \rightarrow CO(g) + 3H_2(g)$$

Given that the reaction is highly endothermic, select the correct choice regarding the spontaneity of this process.

●a. The reaction is only spontaneous at high temperatures.

b. The reaction is never spontaneous at any temperature.

c. The reaction is only spontaneous at low temperatures.

d. The reaction is spontaneous at all temperatures.

Explanation: We are told that $\Delta H > 0$, and from the stoichiometry of the reaction it can be determined that $\Delta S > 0$. Thus, using our expression for Gibbs' free energy ($\Delta G = \Delta H - T\Delta S$) we see that the reaction will only be spontaneous at high temperatures, where the entropic driving force overcomes the enthalpic penalty for this process.

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11. Some alternative methods for hydrogen production have been proposed. One such process utilizes a molten bismuth catalyst to produce hydrogen without generating CO_2. What is correct equilibrium expression for this reaction?

$$CH_4(g) \rightleftharpoons C(s) + 2H_2(g)$$

a. $\frac{(P_{H_2})^2}{P_{CH_4} \cdot P_C}$

b. $\frac{2P_{H_2}}{P_{CH_4}}$

c. $\frac{P_{CH_4} \cdot P_C}{(P_{H_2})^2}$

d. $\frac{P_{CH_4}}{2P_{H_2}}$

●e. $\frac{(P_{H_2})^2}{P_{CH_4}}$

f. $\frac{P_{CH_4}}{(P_{H_2})^2}$

Explanation: Solids (and liquids) are not included in equilibrium expressions (their activities are 1). Thus, the correct answer does not include the C(s). So only two terms are included in the mass action expression and you get $\frac{(P_{H_2})^2}{P_{CH_4}}$.

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12. What are the signs for the change in enthalpy and change in entropy when dissolving a gas into a liquid?

●a. $\Delta H < 0$, $\Delta S < 0$

b. $\Delta H > 0$, $\Delta S < 0$

c. $\Delta H < 0$, $\Delta S > 0$

d. $\Delta H > 0$, $\Delta S > 0$

Explanation: $\Delta H < 0$ because we are forming favorable IMFs between the gas molecules and solvent molecules, whereas there are essentially zero favorable IMFs in the gas phase. This ultimately releases energy, and the process is exothermic. $\Delta S < 0$ because gas molecules dissolved into a liquid are more ordered than undissolved gas molecules.

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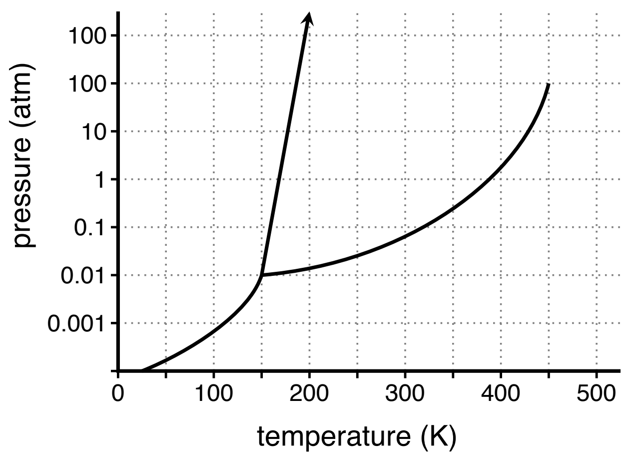
13. (Part 1 of 2) Consider the following phase diagram



What is the normal boiling point of this substance?

a. 430 K

b. 320 K

●c. 385 K

d. 170 K

e. 450 K

f. 150 K

Explanation: Follow the 1 atm line (normal) to the liquid/gas line. That intersection is at 385 K which is the boiling point at that pressure.

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14. (Part 2 of 2) Referring to the previous phase diagram, I keep the temperature constant at 300 K and then steadily reduce the applied pressure from 1 atm down to 0.001 atm. What best describes what I observe?

●a. A liquid will begin boiling until all of it is a gas.

b. A solid will begin melting until all of it is a liquid.

c. A liquid will just remain a liquid.

d. A liquid will begin freezing until all of it solidifies.

e. A gas will begin condensing until all of it is a liquid.

f. A liquid will boil until about half of it is gas and the rest is liquid.

Explanation: Following the vertical line at 300 K from 1 atm down to 0.001 atm, we cross the liquid-gas line which means boiling occurred (while on the line) and we completely make it to gas state. All of it is gas at 0.001 atm.

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15. You take a plane from Austin, TX (Weather: 760 Torr, 80 °F) to Denver, CO (Weather: 630 Torr, 30 °F) and develop several symptoms - dizziness, headache, and nausea - all characteristic of altitude sickness, which is typically attributed to a lack of oxygen in the blood stream. Which of the following answer choices correctly explains this unfortunate phenomenon?

●a. The lower P_{O_2} in Denver means less oxygen can dissolve into blood.

b. The colder air in Denver means less oxygen can dissolve into blood.

c. It is impossible to say.

d. The colder air in Denver means more oxygen can dissolve into blood.

e. The lower P_{O_2} in Denver means more oxygen can dissolve into blood.

Explanation: The air temperature is irrelevant for this problem, your body maintains a constant temperature of 37°C or 98.6 °F. On the other hand, the partial pressure of oxygen in the atmosphere is very important. The reduction of air pressure in denver results in less oxygen dissolving into the bloodstream, leading to the symptoms associated with altitude sickness.

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16. (Part 1 of 2) You are performing the chlorination of acetylene in a piston-cylinder reactor. The reaction show below is currently at equilibrium.

$$C_2H_2(g) + 2Cl_2(g) \rightleftharpoons C_2H_2Cl_4(g)$$

You now perturb the system by depressing the cylinder, halving the total volume of the system. Which answer choice below describes how the systems reacts to this change?

- a. Generate more $C_2H_2Cl_4$
- b. Generate more Cl_2, but not more C_2H_2
- c. Nothing changes
- d. Consume some $C_2H_2Cl_4$
- e. Generate more C_2H_2 and Cl_2
- f. Generate more C_2H_2, but not more Cl_2

Explanation: Compressing a gas-system will shift the equilibrium toward the side with fewer gas molecules. Thus, the only correct choice is to generate more $C_2H_2Cl_4$.

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17. (Part 2 of 2) Considering the same equilibrium reaction/system as above, what would happen if you instead injected enough Cl_2 which would double its partial pressure.?

- a. $P_{C_2H_2}$ will increase
- b. $P_{C_2H_2}$ will increase and P_{Cl_2} will decrease
- c. $P_{C_2H_2Cl_4}$ will decrease
- d. Nothing changes
- e. P_{Cl_2} will continue increasing
- f. $P_{C_2H_2Cl_4}$ will increase

Explanation: Le'Chatelier's principle! If we perturb the system by adding more Cl_2, we will drive the system to generate more products. Thus, the only correct answer is that $P_{C_2H_2Cl_4}$ will increase.

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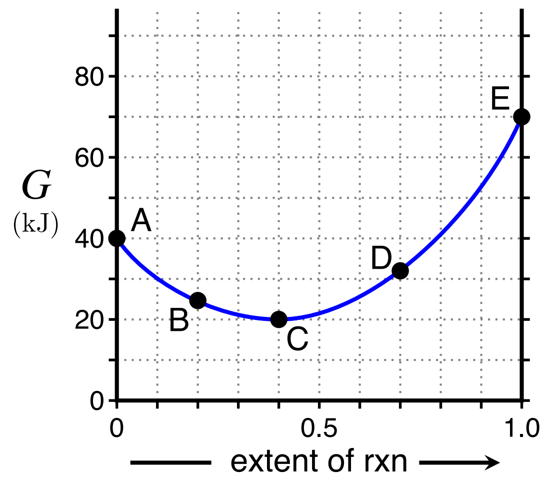
18. (Part 1 of 2) Consider the following free energy vs extent of reaction diagram.



What is the standard free energy ($\Delta G°$) for this reaction?

- a. +30 kJ
- b. −50 kJ
- c. +50 kJ
- d. −20 kJ
- e. −40 kJ
- f. +80 kJ

Explanation: The standard free energy change is just the free energy of the products (point E) minus the free energy of the reactants (point A). 70 - 40 = +30 kJ

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19. (Part 2 of 2) Refer to the previous extent of reaction diagram. A mixture exists with the amounts that correspond to point D on the diagram. Which statement is true as the mixture proceeds to equilibrium?

- a. Q is less than K and the reaction goes in reverse to point C.
- b. Q is greater than K and the reaction goes in reverse to point A.
- c. Q is less than K and the reaction goes forward to point E.
- d. Q is greater than K and the reaction goes in reverse to point C.
- e. Q is equal to K and the reaction is at equilibrium.

Explanation: The equilibrium point is C which has the lowest free energy mixture of reactants and products. Point D has too many products vs C and therefore $Q > K$. The reaction must reverse to go from D to C.

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20. Identify the van't Hoff factors (i) for the following substances: glucose ($C_6H_{12}O_6$), maltose ($C_{12}H_{22}O_{11}$), sodium chloride (NaCl), and calcium chloride ($CaCl_2$).

a. $i_{\text{glucose}} = 1$, $i_{\text{maltose}} = 1$, $i_{\text{NaCl}} = 2$, $i_{\text{CaCl}_2} = 4$

b. $i_{\text{glucose}} = 1$, $i_{\text{maltose}} = 1$, $i_{\text{NaCl}} = 1$, $i_{\text{CaCl}_2} = 1$

●c. $i_{\text{glucose}} = 1$, $i_{\text{maltose}} = 1$, $i_{\text{NaCl}} = 2$, $i_{\text{CaCl}_2} = 3$

d. $i_{\text{glucose}} = 1$, $i_{\text{maltose}} = 1$, $i_{\text{NaCl}} = 2$, $i_{\text{CaCl}_2} = 2$

e. $i_{\text{glucose}} = 1$, $i_{\text{maltose}} = 2$, $i_{\text{NaCl}} = 2$, $i_{\text{CaCl}_2} = 3$

Explanation: Glucose and maltose are both non-electrolytes, thus their van't Hoff factors are both 1. NaCl dissociates into 2 ions, thus its factor is 2, while $CaCl_2$ dissocaites into 3 ions, thus its factor is 3.

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21. Consider the reaction:

$$SF_6(g) \rightleftharpoons SF_4(g) + F_2(g)$$

K_p for this reaction is 0.44 at a temperature of 239 °C. What is the value of $\Delta G°$ for this reaction as shown?

a. +2.85 kJ/mol

b. −1.63 kJ/mol

c. −3.50 kJ/mol

●d. +3.50 kJ/mol

e. −2.85 kJ/mol

f. +1.63 kJ/mol

Explanation: $\Delta G° = -RT \ln K$

$= -8.314(239 + 273.15) \ln(0.44) = 3500$ J/mol

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22. Consider the equilibrium:

$$2X(g) + 2Y(g) \rightleftharpoons 3Z(g)$$

You introduce some X and Y into the reaction vessel and allow the system to equilibrate. The final partial pressures of each component were found to be $P_X =$ 0.88 atm , $P_Y = 2.11$ atm , $P_Z = 6.55$ atm. Calculate K_p.

a. 12.4

b. 0.012

●c. 81.5

d. 3.52

e. 0.081

f. 0.284

Explanation: Know how to set up an equilibrium expression, from there it is plug and chug. $K_p = \frac{(P_Z)^3}{(P_X)^2(P_Y)^2} = \frac{(6.55)^3}{(0.88)^2(2.11)^2} = 81.5$.

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23. Road salt (typically sodium chloride) is added to roads in icy conditions to melt the ice. To test this out, you dissolve 200 g of sodium chloride into 1 L of water and place it into a freezer. What is the new freezing point of this salty solution?

a. $T_{\text{fp}} = +6.4$°C

●b. $T_{\text{fp}} = -12.7$°C

c. $T_{\text{fp}} = -6.4$°C

d. $T_{\text{fp}} = -1.8$°C

e. $T_{\text{fp}} = -3.5$°C

f. $T_{\text{fp}} = +12.7$°C

Explanation: $\Delta T_f = i \cdot k_f \cdot m$; where m is molality. For water, $k_f = 1.86$°C m^{-1}. The molality (mol/kg solvent) is (200 g NaCl)(1 mol NaCl/58.44 g)/(1 kg water) = 3.42 m. Thus, $\Delta T_f = 2 \cdot 1.86 \cdot 3.42 = 12.7$, making the new freezing point -12.7°C.

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24. Using a process known as plasmid vectorization, E. coli cells can be programmed to produce a wide variety of complicated molecules, including antibiotics and proteins. Anyway, which of the following should we do to break open the cells and obtain our desired molecule?

a. None of the other options will burst the cells.

b. Place the cells into water with an osmotic pressure similar to that found inside the cell.

c. Place the cells into very salty water.

d. Sing them a lovely song.

e. Place the cells into pure water.

Explanation: E. coli cells contain electrolytes as well as small molecules which give them an internal osmotic pressure. Adding the cells to pure water allows water to diffuse into the cells to balance the osmotic pressure gradient, causing them to swell and eventually burst.

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25. Consider the stepwise oxidation of methane into CO_2:

1) $2CH_4(g) + 3O_2(g) \rightleftharpoons 2CO(g) + 4H_2O(g) \qquad K_1$

2) $2CO(g) + O_2(g) \rightleftharpoons 2CO_2(g) \qquad K_2$

Where $K_1 = 3.77 \times 10^4$, and $K_2 = 6.46 \times 10^9$

Find K for the overall reaction below:

$CH_4(g) + 2O_2(g) \rightleftharpoons CO_2(g) + 2H_2O(g) \qquad K = ?$

a. $K = 6.41 \times 10^{-8}$

b. $K = 4.11 \times 10^{-15}$

c. $K = 2.43 \times 10^{14}$

d. $K = 5.83 \times 10^{28}$

e. $K = 1.56 \times 10^{7}$

f. $K = 7.73 \times 10^{17}$

Explanation: When we add reactions together, we multiply the equibrium constants to find the new equilibrium constant. The important thing to recognize here is that adding rxn 1 to rxn 2 gives the desired reaction, but doubled. Thus, after multiplying the equilibrium constants together, we must then take the square root. This gives $K = (K_1K_2)^{1/2}$.

After you are finished and have all your answers circled, go to the front of the room and then use the QR code show below to pull up the virtual answer page for your exam. Enter the appropriate info plus all your answers - click the SUBMIT button. Double check your choices on the next page. Once your are sure, click the submit button on that page to enter your answers. Make sure you get the confirmation screen (different background color!) and show it to the TA or proctor. After that, turn in your exam and scratch paper. You're free to leave after that.

https://mccord.cm.utexas.edu/iron

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