

This exam should have 22 questions. The point values are given with each question. Bubble in your answer choices on the bubble sheet provided. Your score is based on what you bubble on the bubble sheet and not what is circled on the exam. Below are some constants you might want to use.

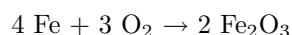
**Water Data**

|                                                                          |                                                            |                                    |
|--------------------------------------------------------------------------|------------------------------------------------------------|------------------------------------|
| $T_{\text{fp}} = 0^{\circ}\text{C}$                                      | $\Delta H_{\text{vap}} = 2260 \text{ J}\cdot\text{g}^{-1}$ | $R = 8.314 \text{ J/mol K}$        |
| $T_{\text{bp}} = 100^{\circ}\text{C}$                                    | $\Delta H_{\text{fus}} = 334 \text{ J}\cdot\text{g}^{-1}$  | $R = 0.08206 \text{ L atm/mol K}$  |
| $C_{\text{ice}} = 2.09 \text{ J}\cdot\text{g}^{-1}\cdot\text{K}^{-1}$    | $K_{\text{b}} = 0.512^{\circ}\text{C/m}$                   | $1 \text{ atm} = 760 \text{ torr}$ |
| $C_{\text{water}} = 4.184 \text{ J}\cdot\text{g}^{-1}\cdot\text{K}^{-1}$ | $K_{\text{f}} = 1.86^{\circ}\text{C/m}$                    |                                    |
| $C_{\text{steam}} = 2.03 \text{ J}\cdot\text{g}^{-1}\cdot\text{K}^{-1}$  |                                                            |                                    |

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- 1 Iron metal will oxidize and turn to rust according to the equation (5 points)



If 115.4 grams of iron metal are allowed to oxidize completely, how many grams of rust will form?

- A. 165.0 g  
B. 57.7 g  
C. 330.0 g  
D. 660.0 g  
E. 118.1 g

**Explanation:** Convert grams of iron to moles. The stoichiometry shows that for every 4 moles of Fe reacted, there are 2 moles of  $\text{Fe}_2\text{O}_3$  created. Convert moles of rust back to grams.

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- 2 Solid  $\text{CO}_2$ , dry ice, will sublime if left out at room temperature. (5 points)

What are the signs of  $\Delta G$ ,  $\Delta H$ , and  $\Delta S$  for this change?

- A.  $\Delta G < 0$ ,  $\Delta H > 0$ ,  $\Delta S > 0$   
B.  $\Delta G < 0$ ,  $\Delta H < 0$ ,  $\Delta S > 0$   
C.  $\Delta G = 0$ ,  $\Delta H > 0$ ,  $\Delta S < 0$   
D.  $\Delta G = 0$ ,  $\Delta H > 0$ ,  $\Delta S > 0$   
E.  $\Delta G > 0$ ,  $\Delta H < 0$ ,  $\Delta S > 0$   
F.  $\Delta G > 0$ ,  $\Delta H > 0$ ,  $\Delta S < 0$

**Explanation:** Sublimation of dry ice left at room temperature is spontaneous ( $\Delta G < 0$ ), requires the absorption of heat from surroundings ( $\Delta H > 0$ ), and involves a phase change from solid to gas ( $\Delta S > 0$ ).

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- 3 How many kilojoules of energy are required to heat 1.5kg of ice at  $-10^{\circ}\text{C}$  until it is water at  $55^{\circ}\text{C}$ ? (5 points)
- A. 377 kJ
  - B. 408 kJ
  - ✓ C. 878 kJ
  - D. 909 kJ
  - E. 637 kJ

**Explanation:** Three steps are required. First warm the ice from  $-10^{\circ}\text{C}$  to  $0^{\circ}\text{C}$ . Next, change phase from solid ice to liquid water. Third, warm the water from  $0^{\circ}\text{C}$  to  $55^{\circ}\text{C}$ .

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- 4 Imagine two 1 liter containers with the lids on. Container A holds 500 mL of pure hexane at  $20^{\circ}\text{C}$ . Container B has 100 mL of pure hexane at  $25^{\circ}\text{C}$ . In which container does the hexane have a higher vapor pressure? (5 points)
- A. Container A
  - ✓ B. Container B
  - C. They both have the same vapor pressure.

**Explanation:** The vapor pressure is independent of the amount of liquid or the volume the gas can occupy. The vapor pressure is directly related to the temperature.

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- 5 You are trying to make your own fizzy water from plain water, and you need a concentration of 0.12 M  $\text{CO}_2$  to achieve proper carbonation. You hook up your  $\text{CO}_2$  tank to a 2.0 L water bottle and set it in your kitchen overnight. What pressure setting should you use on your  $\text{CO}_2$  tank to achieve your desired carbonation level?  $k_{\text{H}}$  for  $\text{CO}_2$  is 29.76 atm/M at  $25^{\circ}\text{C}$ . (5 points)
- ✓ A. 3.6 atm
  - B. 7.1 atm
  - C. 2.5 atm
  - D. 5.0 atm

**Explanation:** Henry's Law:  $P_{\text{CO}_2} = k_{\text{H}}[\text{CO}_2]$ . The volume of the container is irrelevant.

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- 6 What is the molality of an aqueous potassium chloride solution that is 15% KCl by mass? (5 points)
- A. 0.17 *m*
  - B. .0024 *m*
  - ✓ C. 2.4 *m*
  - D. 0.88 *m*
  - E. 1.7 *m*

**Explanation:** Assume 100 grams of solution. KCl is 15 grams. The remaining 85 grams are water. Convert grams of KCl to moles of KCl and put water in units of kilograms.

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- 7 18.2 grams of  $\text{CaCl}_2$  are dissolved into 3.50 L of water at  $10.0^\circ\text{C}$ . (5 points)  
What is the osmotic pressure of the resulting solution?
- A. 0.675 atm
  - B. 2.18 atm
  - C. 4.36 atm
  - ✓ D. 3.27 atm
  - E. 1.09 atm

**Explanation:**  $\Pi = iMRT$ . The Van't Hoff factor for  $\text{CaCl}_2$  is 3.

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- 8 (Part 1 of 2) A scoop of pure sucrose (commonly known as refined sugar - a nonelectrolyte) weighing 266.85 grams is added to 1.00 L of water. The resulting sugar-water solution has a freezing point of  $-1.45^\circ\text{C}$ . What will the boiling point of this solution be?  $k_f$  for water =  $1.86^\circ\text{C}/m$ .  $k_b$  for water =  $0.512^\circ\text{C}/m$ . (5 points)
- ✓ A.  $103.99^\circ\text{C}$
  - B.  $101.45^\circ\text{C}$
  - C.  $100.78^\circ\text{C}$
  - D.  $100.512^\circ\text{C}$
  - E.  $96.01^\circ\text{C}$
  - F.  $98.14^\circ\text{C}$
  - G.  $100.00^\circ\text{C}$

**Explanation:**  $\Delta T_f = k_f * m * i$ . Sucrose does not ionize, so  $i = 1$ . Use the freezing point depression information first to find molality. Then use the molality to find  $\Delta T_b$  for the boiling point elevation. Add  $\Delta T_b$  to the normal boiling point of water,  $100^\circ\text{C}$ , to find the new boiling point.

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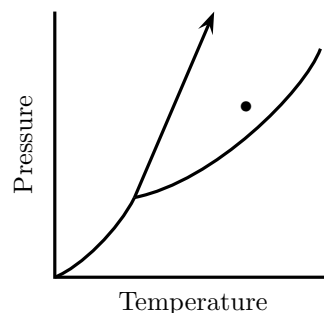
- 9 (Part 2 of 2) Using the information provided in question the previous question, determine the molecular weight of sucrose. The density of water is  $1.00 \text{ g/mL}$ . (5 points)
- A. 267 g/mol
  - ✓ B. 342 g/mol
  - C. 439 g/mol
  - D. 171 g/mol
  - E. 534 g/mol
  - F. 780 g/mol
  - G. The information provided is insufficient to determine the molecular weight.

**Explanation:**  $\Delta T_f = k_f \cdot m \cdot i$ . The molality of the sugar water is  $m = 1.45/1.86 = 0.7796m$ . This is the number of moles of solute (sucrose) per kilogram of solvent (water). The mass of water is  $(1.00\text{L})(1000\text{mL}/1\text{L})(1.00\text{g/mL})=1.00\text{kg}$ . Thus the total mass of sucrose is  $(0.7796 \text{ mol sucrose}/1 \text{ kg solvent})(1\text{kg solvent})=0.7796$  moles. The mass of sucrose used was 266.85 grams. Therefore  $\text{MW}(\text{sucrose})=266.85\text{g}/0.7796\text{mol}=342.29\text{g/mol}$ .

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- 10 Refer to the phase diagram given. What best describes the phase represented by the position of the dot (●)? (3 points)

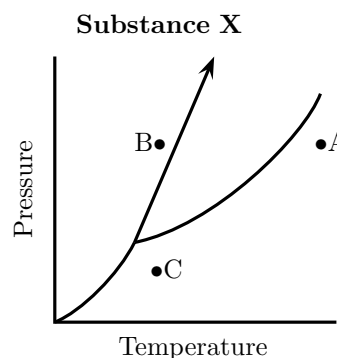
- A. solid
- ✓ B. liquid
- C. gas
- D. solution
- E. suspension
- F. gel
- G. aqueous
- H. plasma



**Explanation:** none

- 11 Refer to the phase diagram provided for Substance X. A sample of Substance X is first observed at a temperature and pressure that correspond to Point A. The temperature is slowly lowered while the pressure is kept constant until reaching the Point B. Then the pressure is slowly lowered while the temperature is kept constant until conditions reach Point C. Which of the following statements best describes what was observed during this process? (3 points)

- A. Substance X went from gas to solid via deposition, then went from solid back to gas via sublimation.
- B. The Substance X sample remained a gas the entire time, though it became cooler and less pressurized.
- ✓ C. The Substance X sample started as a gas, condensed to a liquid, froze to a solid, and then melted back to a liquid before evaporating back to a gas.
- D. Substance X dissolved into liquid, then crystallized into a solid before it fused back into a liquid and then disintegrated into a gas.
- E. The Substance X sample got colder and heavier until it became a solid, then it got warmer and lighter until it became a gas again.



**Explanation:** none

- 12 In which of the following solvents will a salt such as KCl be the most soluble? (5 points)

- ✓ A. ethanol,  $\text{CH}_3\text{CH}_2\text{OH}$
- B. benzene,  $\text{C}_6\text{H}_6$
- C. carbon tetrachloride,  $\text{CCl}_4$
- D. ethyl ether,  $\text{C}_2\text{H}_5\text{OC}_2\text{H}_5$
- E. chloroform,  $\text{CHCl}_3$

**Explanation:** A salt will be most soluble in the most polar solvent. Ethanol is the only polar solvent listed that has H-bonding which makes it the best solvent of those listed.

- 13 James boils a pot of miracle organic oil at his art studio in Taos, New Mexico (elevation 7,000 ft above sea level, local air pressure = 0.77 atm). His compost-powered thermometer informs him that his oil boils at 129.5°C. Sarah boils a pot of miracle organic oil in her vacation camper in Death Valley, California (elevation 280 ft below sea level, local air pressure = 1.16 atm). Her bluetooth-enabled thermometer reads that her oil boils at 136.3°C. What is the enthalpy of vaporization of the miracle organic oil? (5 points)
- ✓ A. 82.6 kJ/mol
  - B. 82601 kJ/mol
  - C. 8.84 kJ/mol
  - D. 8842 kJ/mol
  - E. 35.9 kJ/mol
  - F. -35873 kJ/mol
  - G. -82.6 kJ/mol
  - H. -8.84 kJ/mol
  - I. -35.9 kJ/mol
  - J. -8842 kJ/mol

**Explanation:** Use the Clausius-Clapeyron equation. Let  $P_1$  and  $T_1$  represent one set of measurements, such as those in Taos. Let  $P_2$  and  $T_2$  represent the other measurements, in Death Valley. Be sure that  $T$  is in Kelvin. Solve for  $\Delta H_{\text{vap}}$ , which will be a positive value because a substance must absorb energy in order to change phase to vapor.

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- 14 Consider the reaction (5 points)



If the concentration of A is cut in half, what will happen to the value of  $K$ ?

- ✓ A.  $K$  does not change.
- B.  $K$  decreases by one-fourth.
- C.  $K$  increases by a factor of four.
- D.  $K$  decreases by one-half.
- E.  $K$  increases by a factor of two.
- F.  $K$  increases because the reaction will shift toward the product side to relieve the stress.

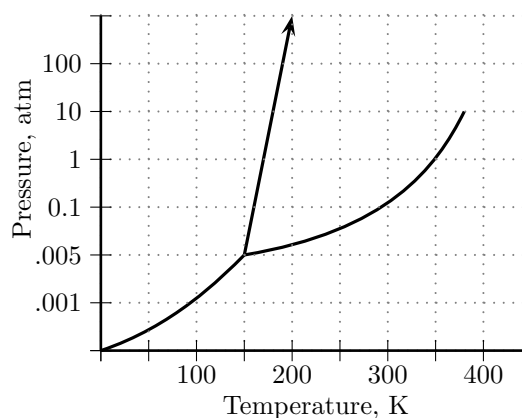
**Explanation:** For any given reaction at a given temperature,  $K$  is, by definition, a constant.

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15 A phase diagram is shown to the right. What is the normal boiling point of this substance?

(3 points)

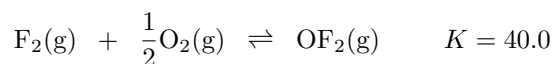
- A. 150 K
- ✓ B. 350 K
- C. 375 K
- D. 290 K
- E. 160 K
- F. 170 K
- G. 180 K



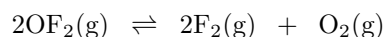
**Explanation:** Following the 1 atm line across, the liquid/gas line is crossed at 350 K.

16 Consider the following reaction and the value of  $K$

(5 points)



What is the value of  $K$  for the reaction:



- ✓ A.  $6.25 \times 10^{-4}$
- B.  $1.60 \times 10^3$
- C.  $2.50 \times 10^{-2}$
- D.  $1.25 \times 10^{-2}$
- E.  $8.00 \times 10^2$
- F.  $3.75 \times 10^{-3}$

**Explanation:** The reaction is flipped and doubled so that the new  $K' = \frac{1}{K^2} = \frac{1}{40^2} = \frac{1}{1600} = 6.25 \times 10^{-4}$ .

17 Consider the simple reaction:  $\text{Br}_2(\text{g}) \rightleftharpoons 2\text{Br}(\text{g})$

(5 points)

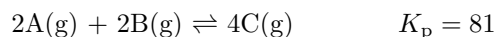
At 3500 K,  $K_p = 22.2$ . What is the value of  $K_c$  for this reaction?

- A.  $2.25 \times 10^3$
- ✓ B.  $7.73 \times 10^{-2}$
- C.  $6.55 \times 10^7$
- D.  $1.91 \times 10^{12}$
- E.  $8.32 \times 10^{-4}$
- F.  $2.66 \times 10^{-6}$

**Explanation:** Use  $K_p = K_c(RT)^{\Delta n}$  where  $\Delta n = 2 - 1 = 1$ .

$$K_c = 22.2(0.08206 \cdot 3500)^{-1} = 7.73 \times 10^{-2}$$

18 Consider the following general gas phase reaction: (5 points)



Now consider that the reaction chamber is pumped up such that the partial pressures of both A and B are 3.0 atm. What is the final partial pressure of C after equilibrium is established?

- A. 1.2 atm
- B. 2.4 atm
- ✓ C. 3.6 atm
- D. 4.8 atm
- E. 6.0 atm

**Explanation:** An easy first step (although not absolutely necessary) is to see that you can divide the equation by 2 and have just



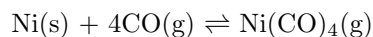
Then you set up a RICE table and get the following algebraic equation to solve

$$9 = \frac{(2x)^2}{(3-x)^2}$$

Solve by taking the square root of both sides and then you get  $x = 9/5 = 1.8$ . The pressure of C would be  $2x$  here and that gives 3.6 atm.

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19 (Part 1 of 2) Consider following reaction at equilibrium. (3 points)



What happens to the reaction mixture if the entire mixture is now compressed to a smaller volume?

- A. nothing happens
- B. more CO is made
- C. more Ni is made
- ✓ D. more  $Ni(CO)_4$  is made

**Explanation:** Compressing an equilibrium mixture will “push” the reaction more towards the side with the fewest gas moles which in this case is the  $Ni(CO)_4$  side

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20 (Part 2 of 2) What happens if exactly one half of the nickel is removed from the reaction chamber? (3 points)

- ✓ A. nothing happens
- B. the CO doubles in amount
- C. the Ni then doubles back to its original amount
- D. the  $Ni(CO)_4$  doubles in amount

**Explanation:** Ni is a solid and has an activity of one no matter what quantity there is, as long as there is some. So varying the amount of nickel does nothing to the equilibrium amounts originally present.

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21 Consider the reaction:  $\text{PCl}_5(\text{g}) \rightleftharpoons \text{PCl}_3(\text{g}) + \text{Cl}_2(\text{g})$  (5 points)

$K_p$  for this reaction is 1.92 at a temperature of  $252^\circ\text{C}$ . What is the value of  $\Delta G^\circ$  for this reaction as shown?

- ✓ A. -2.85 kJ
- B. -1.37 kJ
- C. -1.24 kJ
- D. -28.1 kJ
- E. +2.85 kJ
- F. +1.37 kJ
- G. +1.24 kJ
- H. +28.1 J
- I. 0 J

**Explanation:**  $\Delta G^\circ = -RT \ln K = -8.314(252 + 273.15) \ln(1.92) = -2848\text{J}$

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22 Consider the equilibrium:  $\text{X}(\text{g}) + 2\text{Y}(\text{g}) \rightleftharpoons 3\text{Z}(\text{g})$  (5 points)

X and Y are both introduced to an empty reaction chamber such that the partial pressure of X is 2 atm and the partial pressure of Y is 3 atm. There is no Z initially present. After the reaction reaches equilibrium the partial pressure of Y is found to be 1 atm. What is the value of  $K_p$  for this reaction?

- ✓ A. 27
- B. 9
- C. 2
- D. 13.5
- E. 3
- F. 1
- G. 4.5
- H.  $\infty$

**Explanation:** After setting up the correct RICE table you will know that the equilibrium values for X, Y, and Z are  $2-x$ ,  $3-2x$ , and  $3x$  respectively. You were told that Y is 1 atm. That means that  $x=1$ . So the final values for partial pressures are  $X=1$ ,  $Y=1$ , and  $Z=3$ . Plug those into the mass action expression to get  $K_p$  which is  $3^3 = 27$ .

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Remember to bubble in ALL your answers BEFORE time is called. Sign your bubblesheet AND your exam. Then turn in BOTH your exam copy and your bubblesheet.