Exam 4

# Part 1: Multiple Choice (2 points each)

## Directions: Please circle the *best* answer for each of the following questions.

1. In order for a solute to dissolve in a solvent, there must be:
	1. Ion-dipole forces between solvent molecules.
	2. Repulsion between solvent and solute molecules.
	3. Intermolecular attractions between solvent and solute molecules.
	4. Weak intermolecular forces between solute molecules.
	5. all of the above
2. Fresh vegetables with high water content do not freeze well because
	1. water expands when it freezes and damages the cell wall.
	2. water contracts when it freezes and damages the cell wall.
	3. water expands when it freezes and does not damage the cell wall.
	4. water contracts when it freezes and does not damage the cell wall.
	5. water does not change in size when it freezes.
3. Choose the substance with the lowest surface tension.
	1. CH3SeCH2CH3
	2. CH3CH2CH2CH3
	3. C6H6
	4. H2Se
	5. (CH3)2SO
4. Which solute has the highest van’t Hoff factor?
	1. Nonelectrolyte
	2. KI
	3. MgSO4
	4. CaCl2
	5. AlCl3
5. Identify the element with the smallest band gap.
	1. Carbon
	2. Silicon
	3. Germanium
	4. Lead
	5. Oxygen
6. Identify the type of interaction between atoms in a nonbonding atomic solid.
	1. Polar bonding
	2. Ionic bonding
	3. Covalent bonding
	4. Hydrogen bonding
	5. Weak dispersion forces
7. Equilibrium for a chemical reaction is often called dynamic equilibrium because:
	1. a chemical reaction only truly stops when all reactants have been turned into products.
	2. a chemical reaction only seems to stop when it reaches equilibrium.
	3. reactants have changed into products, and dynamic means change.
	4. it is an important concept, and dynamic reminds us of this importance.
	5. the reactants and products are equal.

Heating a metal carbonate leads to decomposition

BaCO3 (s) $⇌$ BaO (s) + 2 CO2 (g)

Predict the effect on the equilibrium of the changes listed below.

1. adding BaCO3:
	1. no change
	2. shifts left
	3. shifts right
	4. increases T
	5. none of the above
2. decrease the volume of the flask containing the reaction:
	1. no change
	2. shifts left
	3. shifts right
	4. increases T
	5. none of the above
3. When using the safety shower for a large spill on yourself, you should:
4. rinse for at least 15 minutes.
5. avoid, it’s not that bad.
6. keep contaminated clothes on.
7. all of the above
8. none of the above

# Part 2: Short Answer

## Directions: Answer each of the following questions. Be sure to use complete sentences where appropriate. For full credit be sure to show all of your work.

1. Explain what happens to a substance when it is heated in a closed container to its critical temperature (3 points).

As the temperature rises, more liquid vaporizes and the pressure within the container increases. As more and more gas is forced into the same amount of space, the density of the gas becomes higher and higher. At the same time, the increasing temperature causes the density of the liquid to become lower and lower. At the critical temperature, the meniscus between the liquid and gas disappears and the gas and liquid phases commingle to form a supercritical fluid.

1. When a thin glass tube is put into water, the water rises 1.4 cm. When the same tube is put into hexane, the hexane rises only 0.4 cm. Explain (3 points).

Water can general strong adhesive interactions with the glass (due to the dipoles at the surface of the glass), but hexane is nonpolar and cannot interact strongly with the glass surface.

1. Why isn’t pentanol (CH3CH2CH2CH2CH2OH) very soluble in water (4 points)?

Even though the pentanol molecule contains a hydrogen bonding portion, the bulk of the bulk of the molecule is nonpolar and only exhibits dispersions forces. The majority of the molecules will not hydrogen bond to the water molecules, making it difficult to dissolve.

1. A solution prepared from 1.25 g of oil of wintergreen (methyl salicylate, boiling point 80.10 °C) in a 99.0 g of benzene (kb = 2.53 °C/*m*) has a boiling point of 80.31 °C. Determine the molar mass of this compound (10 points).

$$∆T\_{b}=ik\_{b}m⇒m=\frac{n\_{solute}}{kg\_{solvent}}=\frac{∆T\_{b}}{ik\_{b}}=\frac{(80.31 ℃-80.10 ℃)}{\left(1\right)\left(2.53\frac{℃}{m}\right)}=\frac{(0.21 ℃)}{\left(1\right)\left(2.53\frac{℃}{m}\right)}=0.083003953\frac{mol}{kg solvent}×99.0 g solvent×\frac{1 kg}{1000 g}=0.008217391 mol $$

$$MM=\frac{m}{n}=\frac{1.25 g}{0.008217391 mol }=152.1164021\frac{g}{mol}≈150\frac{g}{mol}$$

1. Silver crystallizes in a face-centered cubic unit cell. Each side of the unit cell has a length of 409 pm (6 points).
	1. What is the radius of a silver atom?

$l=2\sqrt{2}r⇒r=\frac{l}{2\sqrt{2}}=\frac{409 pm}{2\sqrt{2}}=145 pm$

* 1. If the atomic radius of silver is 153 pm, what is the percent error?

$$\%error=\frac{observed value-true value}{true value}×100$$

$$\%error=\frac{145 pm-153 pm}{153 pm}×100$$

$$\%error=\frac{-8 pm}{153 pm}×100=-5\%$$

1. Suppose 651 g of ethylene glycol, HOCH2CH2OH, is dissolved in 1.50 kg of water. What is the vapor pressure of the water over the solution at 90 °C? The vapor pressure of pure water at 90 °C is 525.8 mm Hg. Assume ideal behavior for the solution (10 points).

$$n\_{water}=1.50 kg H\_{2}O×\frac{1000 g}{1 kg}×\frac{1 mol H\_{2}O}{18.015 g H\_{2}O}=83.3 mol H\_{2}O$$

$$n\_{glycol}=651 g HOCH\_{2}CH\_{2}OH×\frac{1 mol HOCH\_{2}CH\_{2}OH}{62.068 g HOCH\_{2}CH\_{2}OH}=10.5 mol HOCH\_{2}CH\_{2}OH$$

$$χ\_{water}=\frac{n\_{solvent}}{n\_{solution}}=\frac{n\_{water}}{n\_{water}+n\_{glycol}}$$

$$χ\_{water}=\frac{83.3 mol}{83.3 mol+10.5 mol}=\frac{83.3 mol}{93.8 mol}=0.888$$

$$P\_{solution}=χ\_{solvent}P\_{solvent}^{°}$$

$$P\_{solution}=\left(0.888\right)\left(525.8 mmHg\right)=467 mm Hg$$

$$∆P\_{water}=P\_{water}^{°}-P\_{water}=525.8 mm Hg-467 mm Hg=59 mm Hg$$

1. Sketch the phase diagram of benzene. Make sure to label the axes and the different phases of benzene. Use the physical data provided below (6 points).

Melting point = 6 °C

Boiling point = 80 °C

Tc = 289 °C

Pc = 36708 torr

Triple Points = 38 torr, 6 °C

Students should show a graph of Pressure as a function of temperature. Label each phase as solid, liquid or gas. Be sure to specify the critical point, triple point, and that at 760 torr the melting and boiling points begin.

1. Phosphoric acid is made commercially by reacting sulfuric acid with phosphate rock, which contains calcium phosphate (assume that all other materials are inert). The acid solution is 25.0% sulfuric acid by mass and its density is 1.203 g/mL (18 points).
	1. How many liters of sulfuric acid solution are needed to react with 10.0 kg of phosphate rock that is 54.7% calcium phosphate?

Ca3(PO4)2 (s) + 3 H2SO4 (aq) → 3 CaSO4 (s) + 2 H3PO4 (aq)

$$10.0 kg rock×\frac{54.7 kg Ca\_{3}(PO\_{4})\_{2}}{100 kg rock}×\frac{1 kmol Ca\_{3}(PO\_{4})\_{2}}{310.18 kg Ca\_{3}(PO\_{4})\_{2}}×\frac{3 kmol H\_{2}SO\_{4}}{1 kmol Ca\_{3}(PO\_{4})\_{2}}×\frac{98.09 kg H\_{2}SO\_{4} }{1 kmol H\_{2}SO\_{4}}×\frac{100 kg H\_{2}SO\_{4} soln}{25.0 kg H\_{2}SO\_{4}}×\frac{1 L H\_{2}SO\_{4} soln}{1.203 kg H\_{2}SO\_{4} soln}=17.25 L H\_{2}SO\_{4} soln$$

* 1. What is the molality of the sulfuric acid solution?

$$\frac{25.0 g H\_{2}SO\_{4}}{100 g soln}=\frac{25.0 g H\_{2}SO\_{4}}{75.0 g water}×\frac{1000 g soln}{1 kg soln}×\frac{1 mol H\_{2}SO\_{4}}{98.09 g H\_{2}SO\_{4}}=\frac{3.40 mol H\_{2}SO\_{4}}{1 kg water}$$

* 1. What is the mole fraction of sulfuric acid in the solution?

$$25.0 g H\_{2}SO\_{4}×\frac{1 mol H\_{2}SO\_{4}}{98.09 g H\_{2}SO\_{4}}=0.255 mol H\_{2}SO\_{4} $$

$$75.0 g water×\frac{1 mol water}{18.02 g water}=4.16 mol water$$

$$χ\_{H\_{2}SO\_{4}}=\frac{0.255 mol H\_{2}SO\_{4}}{0.255 mol H\_{2}SO\_{4}+4.16 mol water}=\frac{0.255 mol H\_{2}SO\_{4}}{4.41 mol total}=0.0578$$

1. Calculate K for the reaction (8 points):

SnO2 (s) + 2 CO (g) $⇌$ Sn (s) + 2 CO2 (g) K = ?

given the following information:

SnO2 (s) + 2 H2 (g) $⇌$ Sn (s) + 2 H2O (g) K1 = 8.12

H2 (g) + CO2 (g) $⇌$ H2O (g) + CO (g) K2 = 0.771

 SnO2 (s) + 2 H2 (g) $⇌$ Sn (s) + 2 H2O (g) K1 = 8.12

+ 2 H2O (g) + 2 CO (g) $⇌$ 2 H2 (g) + 2 CO2 (g) $K\_{3}=\frac{1}{K\_{2}^{2}}=\frac{1}{(0.771)^{2}}$

SnO2 (s) + 2 CO (g) $⇌$ Sn (s) + 2 CO2 (g) $K=K\_{1}×\frac{1}{K\_{2}^{2}}=\left(8.12\right)\left(\frac{1}{(0.771)^{2}}\right)=13.7$

1. Carbonyl bromide decomposed to carbon monoxide and bromine (12 points).

COBr2 (g) $⇌$ CO (g) + Br2 (g) Kc is 0.190 at 73 °C.

* 1. If you place 0.500 mol of COBr2 in a 2.00 L flask and heat it to 73 °C, what are the equilibrium concentrations of COBr2, CO, and Br2?

|  |  |  |  |
| --- | --- | --- | --- |
|  | COBr2 (g) $⇌$ | CO (g) + | Br2 (g |
| I | $$\frac{0.500 mol }{2.00 L}=0.250 M$$ | 0 M | 0 M |
| C | -x | +x | +x |
| E | 0.250 M – x =0.250 M – 0.143 M =0.107 M | x = 0.143 M | x = 0.143 M |

$$K\_{c}=0.190=\frac{\left[CO\right][Br\_{2}]}{[COBr\_{2}]}$$

$$K\_{c}=0.190=\frac{(x)(x)}{(0.250 M-x)}$$

$$0.0475-0.190x=x^{2}$$

$$x^{2}+0.190x-0.0475=0$$

$$x=\frac{-b\pm \sqrt{b^{2}-4ac}}{2a}=\frac{-0.190\pm \sqrt{(0.190)^{2}-4(1)(-0.0475)}}{2(1)}$$

$$x\_{+}=0.142749619 M≈0.143 M and x\_{-}=-0.332749869 M, which does not make sense.$$

So, x = 0.143 M, plug this into the ICE table to obtain the equilibrium values.

Check your answer:

$$K\_{c}=0.190=\frac{(0.143 M)(0.143 M)}{(0.107 M)}=0.19111215≈0.190$$

* 1. What percentage of the original COBr2 decomposed at this temperature?

$$\%COBr\_{2} remaining=\frac{0.107 M}{0.250 M}×100=42.8\% COBr\_{2} remaining$$

$$\%COBr\_{2} decomposed=100-42.8\%=57.2\% COBr\_{2} decomposed. $$