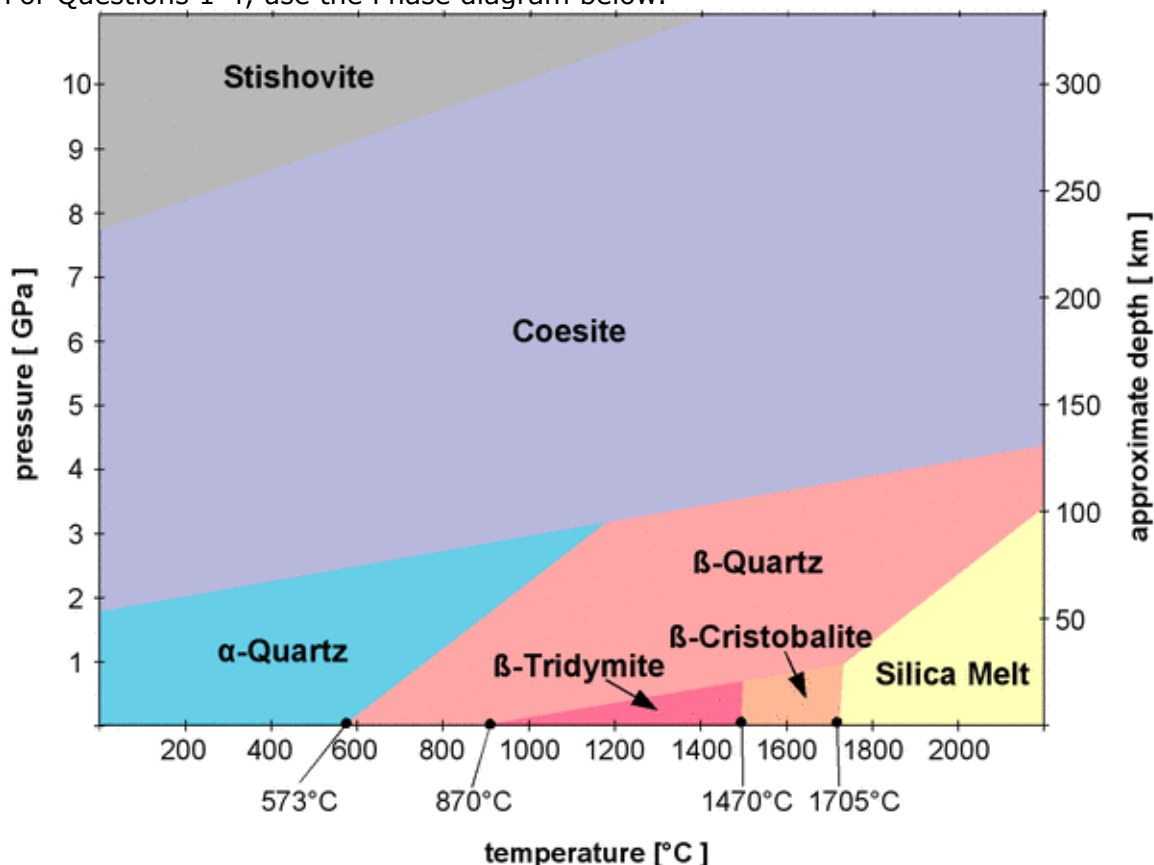


## CH302 Worksheet 1 Answer Key for Physical Equilibria Problems from Lectures 1 through 3

For Questions 1-4, use the Phase diagram below.



1. What is a good general definition of the term triple point? How many triple points are found in the phase diagram for quartz shown above?

A triple point is any point at which three distinct phases of a given species are in equilibrium. In terms of a phase diagram, a triple point is any point at which 3 phase boundaries intersect. There are 3 in the figure above.

2. How many phase boundaries are there in the phase diagram for quartz shown above? (Hint: two of them are found on the same line.)

There are 9 phase boundaries. The line separating Coesite from α-Quartz and β-Quartz is two phase boundaries.

3. Starting at 0.1 GPa and 200 °C and isobarically raising the temperature to 2000 °C, how many phase transitions would occur? What would the final phase be?

There would be 4 phase transitions and the final phase would be Silica Melt.

4. What is a critical point? How many are shown in the phase diagram above?

A critical point is a point temperature beyond which the species is a supercritical fluid, regardless of the applied pressure. There are none in the diagram above.

5. Write as many assumptions involved in the derivation of the Clausius-Clapeyron equation as you can.

We assume that  $\Delta S_{\text{vap}}$  is a constant, which itself assumes the gas phase acts as an ideal gas.

We assume that  $\Delta H_{\text{vap}}$  has a value unaffected by temperature or pressure.

We assume that external pressure doesn't influence vapor pressure.

6. Starting from the general Clausius-Clapeyron equation and performing algebraic rearrangements, express  $P_2$  in terms of the other variables.

$$\ln(P_2/P_1) = (\Delta H_{\text{vap}}/R) * (1/T_1 - 1/T_2)$$

$$P_2 = \{e^{[(\Delta H_{\text{vap}}/R) * (1/T_1 - 1/T_2)]}\} * P_1$$

7. Starting from the general Clausius-Clapeyron equation and performing algebraic rearrangements, express  $T_2$  in terms of the other variables.

$$\ln(P_2/P_1) = (\Delta H_{\text{vap}}/R) \cdot (1/T_1 - 1/T_2)$$

$$T_2 = \{-[\ln(P_2/P_1)]/(\Delta H_{\text{vap}}/R) - 1/T_1\}^{-1}$$

8. When ranking different species in terms of their vapor pressures at a given temperature, what property has the most predictive value?

Intermolecular forces (IMF).

9. Explain the reason for the answer to number 8 in terms of enthalpy of vaporization  $\Delta H_{\text{vap}}$ .

Intermolecular forces (IMF) are the attractive forces that exist between molecules. As the strength of these bonds increases, the amount of energy required to break these bonds increases as well. Hence,  $\Delta H_{\text{vap}}$  increases allowing us to make qualitative predictions about vapor pressure according to IMF.

10. Regardless of the phase change in question, what can you always say about the sign of  $\Delta H$  and  $\Delta S$  relative to one another?

The sign of  $\Delta H$  and  $\Delta S$  are always the same during a phase change - if one is positive the other must be positive as well.

11. What are all of the endothermic phase transitions?

Melting, vaporization and sublimation are all endothermic phase transitions.

12. What general equation describes heat exchange for a system that **is not** at a phase transition?

What do the terms mean? What are their typical units?

$$q = m \cdot c \cdot \Delta T$$

q is heat, with units of joules, J.

m is mass, with units of grams, g.

c is heat capacity, with units of  $\text{J} \cdot \text{g}^{-1} \cdot \text{K}^{-1}$  (same as  $\text{J} \cdot \text{g}^{-1} \cdot ^\circ\text{C}^{-1}$ ).

$\Delta T$  is change in temperature, with units of K (or  $^\circ\text{C}$ ).

13. What general equation describes heat exchange for a system that **is** at a phase transition? What do the terms mean? What are their typical units?

$$q = m \cdot \Delta H$$

q is heat, with units of joules, J.

m is mass, with units of grams, g.

$\Delta H$  is change in enthalpy (for that particular phase transition), with units of  $\text{J} \cdot \text{g}^{-1}$ .

14. What three general steps are involved in dissolving salts in water? Are they endothermic or exothermic steps? Why?

One, expand the solute, endothermic because ion-ion interactions must be broken.

Two, expand the solvent, endothermic because hydrogen bonds must be broken.

Three, form solute-solvent bonds, exothermic because new bonds are formed.

15. Of the three steps above, which one is most likely to have a nearly constant value regardless of the salt involved? Which one is most strongly influenced by the lattice energy of the salt?

Step two requires breaking hydrogen bonds, which has a more or less fixed energetic cost.

Step one requires disrupting the crystal lattice.

16. Dissolution of all gases is an exothermic process. Why?

Whenever a gas molecule collides with an aqueous surface and enters the aqueous phase, it slows down considerably and the difference in kinetic energy is released as heat.

17. Some scientists have claimed that greenhouse gases such as  $\text{CO}_2$  are not a threat to our environment because the world's oceans can absorb huge amounts of such gases. Based on your understanding of dissolution of gases in water and physical equilibria, why doesn't this argument make sense? (Hint: there are lots of good reasons, but one will do.)

As the average temperature of the world's oceans increases, the solubility of gases will actually decrease, making the ocean a poorer and poorer sink for greenhouse gases. Or, a more rhetorical

argument, since gas dissolution is an equilibrium process, and the earth is about 4.5 billion years old, it stands to reason the oceans have already absorbed as much gas as they're going to. Let me (Travis) know if you think of another good argument.

18. The axiom "like dissolves like" is often used to describe miscibility. What does this axiom really mean?

In simplest terms it means that a given liquid will be most soluble in another liquid with similar intermolecular forces (IMF), e.g. non-polar liquids are highly miscible in each other and polar liquids are highly miscible in each other, but non-polar liquids aren't highly miscible in polar liquids.

19. List the four main types of intermolecular forces (IMF) that we've learned about so far in order from weakest to strongest. Which 3 are relevant when thinking about miscibility? Why?

Dispersion forces are weakest, followed by dipole-dipole interactions, then hydrogen bonding and lastly ion-ion interactions are strongest. Only the first 3 are relevant to miscibility, because miscibility is the extent to which *liquids* can mix with one another, and ion-ion interactions typically results in only *solid* species.

20. How is the strength of IMF rated for the four types of IMF you listed in question 19?

dispersion forces - size, i.e molecular weight

dipole-dipole interactions - net dipole moment

hydrogen bonding - number and type of hydrogen bonding partners

ion-ion interaction - charge density