CH353 – Physical Chemistry I
Spring 2012, Unique 52135

Exam 1
Friday, 3 February 2012

Name: Key

Useful Information:

$R = 8.314\ \text{J K}^{-1}\ \text{mol}^{-1} = 8.206 \times 10^{-2}\ \text{L atm mol}^{-1}\ \text{K}^{-1}$

$1\ \text{atm} = 1.01325\ \text{bar} = 1.01325 \times 10^{5}\ \text{Pa} = 760\ \text{Torr}$

$0\ ^{\circ}\text{C} = 273.15\ \text{K}$

Always assume ideal gas unless directed otherwise.

Honor Code:

"The core values of the University of Texas at Austin are learning, discovery, freedom, leadership, individual opportunity, and responsibility. Each member of the University is expected to uphold these values through integrity, honesty, trust, fairness, and respect toward peers and community."

I certify that the work on this exam is entirely my own.

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Signature Date

1. (27 points) Indicate whether the following statements are true or false.

a. True False Humid air is denser than dry air.

b. True False Only charged atoms or molecules will have van der Waals intermolecular forces.

c. True False Work and heat are path functions.

d. True False In a closed system, matter can be exchanged between system and surroundings, but energy cannot.

e. True False For any transformation, $\Delta U = \Delta H$ always.

f. True False For any ideal gas, $C_p > C_v$ always.

g. True False Volume is an intensive property.

h. True False Boyle's law describes how the change in temperature of a thermodynamic system depends on pressure.

i. True False At high enough P, all species will have $Z > 1$.

2. (15 points) Circle the multiple choice answer that correctly answers the question.

a. Which of the following describes an ideal gas?
   i) Particles in this gas rarely collide with the walls of the container.
   ii) Particles in this gas can be described as noninteracting point spheres.
   iii) Particles in this gas are very small compared to the distance between each other.
   iv) All of the above.
   v) None of the above.

b. Which of the following describes a van der Waals gas with $Z < 1$?
   i) This gas is dominated by repulsive intermolecular forces.
   ii) This gas has a larger molar volume than if it were behaving as an ideal gas.
   iii) This gas has a smaller pressure than if it were behaving as an ideal gas.
   iv) All of the above.
   v) None of the above.

c. Which of the following describes a thermodynamic path in which pressure is held constant?
   i) The temperature of the system must remain constant.
   ii) The path must also be reversible.
   iii) The pressure must be held at 1 atm.
   iv) All of the above.
   v) None of the above.

3. (20 points) For each of the following transformations, determine whether q, w, ΔU, and ΔH of the system are greater than zero, less than zero, or equal to zero.

a) Air is sealed in a container with rigid walls and then heated from room temperature to 90°C.

rigid walls $\Rightarrow \Delta V = 0 \Rightarrow \boxed{w = 0}$

$\Delta T > 0 \Rightarrow \boxed{\Delta U > 0,\ \Delta H > 0}$

$q = \Delta U - w \Rightarrow \boxed{q > 0}$

b) Gas in a cylinder 5.0 L in volume is compressed by a constant external pressure of 4.0 atm to a final volume of 1.0 L.

$\Delta P = 0$

$\Delta V < 0 \Rightarrow \boxed{w > 0}$

$\Delta T > 0 \Rightarrow \boxed{\Delta U > 0,\ \Delta H > 0}$

$q = \Delta U - w \Rightarrow \boxed{q > 0}$

c) Water is heated in an open beaker in a laboratory from room temperature to 100°C.

$\Delta T > 0$ $\Delta P = 0$ liquid → hot liquid, $\Delta V = 0$

$\boxed{w = -P\Delta V = 0}$

$\boxed{\Delta H = nC_p\Delta T > 0}$

$\boxed{\Delta U = \Delta H - P\Delta V > 0}$

$\boxed{q = \Delta U - w > 0}$

d) The battery of your laptop discharges completely, performing 100 J of electrical work and releasing 25 J of heat into the room.

$\boxed{q < 0}$

$\boxed{w < 0}$ not PV work

$\boxed{\Delta U = q + w < 0}$

$\boxed{\Delta H = \Delta U + \Delta(PV) < 0}$ no PV work

4. (18 points)

a) A sealed vessel containing an ideal gas at a pressure of 0.5 atm is opened in a room at approximately atmospheric pressure (1.0 atm). What happens?

gas from the surroundings enters the system.

b) A sealed vessel containing an ideal gas at a pressure of 1.5 atm is opened in the same room. What happens?

gas from the system moves to the surroundings

c) The pressure of a poisonous gas inside a sealed vessel is 1.47 atm at 20°C. If the atmospheric pressure is 1.0 atm, to what temperature must the container and its contents be cooled so that the container can be opened with no risk for gas escaping?

Want the $P_{sys} < 1$ atm, say 0.99 atm

$PV = nRT$

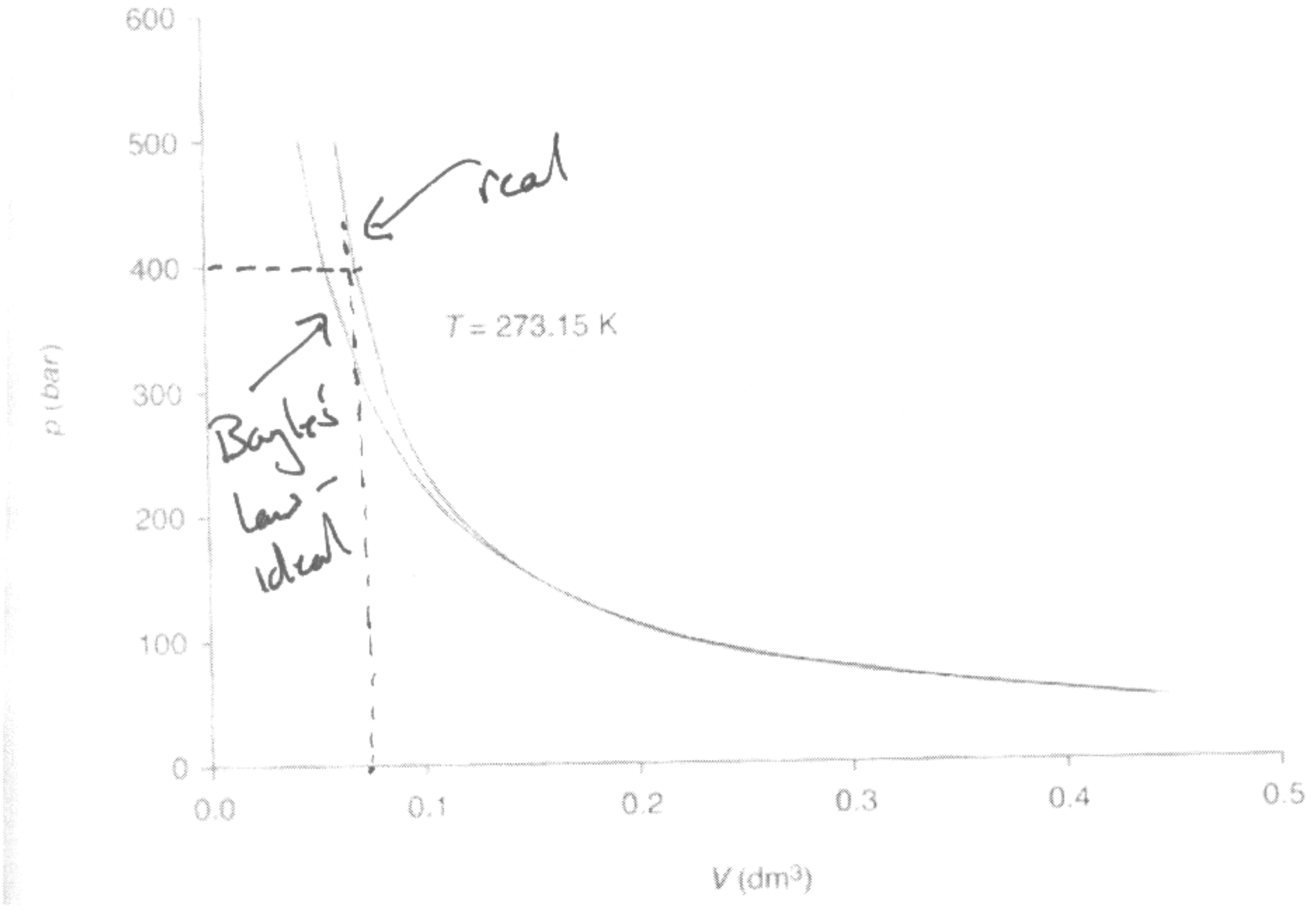
$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$; $T_2 = \frac{P_2V_2T_1}{P_1V_1}$ $\quad V_2 = V_1$

$T_2 = \frac{P_2T_1}{P_1} = \frac{(0.99\text{atm})(293\text{K})}{1.47\text{atm}}$

$T_2 = 197$ K

in order to keep all gas in system.

5. (20 points) The following (slightly tilted) figure shows the Boyle's law behavior of an ideal gas and a real gas, both at 273 K. Use this figure to answer the following questions.



a) Mark on the figure which curve corresponds to Boyle's law and which corresponds to a real gas.

b) In words, describe exactly how you made your decision in part a).

At high enough pressure, all gasses will become dominated by repulsive forces. Therefore, at a given small volume, P(real) > P(ideal). Another way to say that is at a given large pressure, V(real) > V(ideal). Both are drawn on the figure.

c) In words, describe the physical mechanism causing the differences between the two curves.

As atoms and molecules are pushed too close together, they are forced to occupy the same volume. This is a strongly repulsive interaction which will force the species apart, and cause the actual pressure of the system to rise.