ANSWER KEY

1) Show that at 0°C a pressure of 1 atm supports a column of mercury (Hg) in a barometer to a height of 760 mm. Density of mercury at 0°C is 13.5951 g cm^{-3}. **(5 points)**

$P = h \times d \times g$ (2)

$1\ atm = 1.01325 \times 10^5\ kg\,m^{-1}\,s^{-2} = h \times \frac{13.5951 \times 10^{-3}\ kg}{(10^{-2})^3\ m^3} \times 9.80665\ m/s^2$

$h = \frac{1.01325 \times 10^5\ kg\,m^{-1}\,s^{-2} \times 10^{-6}\ m^3}{13.5951 \times 10^{-3}\ kg \times 9.80665\ m\,s^{-2}}$ (3)

$= 0.760\ m$

or 760 mm

2) Calculate the volume of carbon dioxide, at 25°C and 1.0 atm that plants need to make 1.00 g of glucose, $C_6H_{12}O_6$, by photosynthesis in the reaction:

$6\ CO_2(g) + 6\ H_2O(l) \rightarrow C_6H_{12}O_6\ (s) + 6\ O_2(g)$ **(6 points)**

Molar Mass of $C_6H_{12}O_6 = 180.1\ g/mol$ (2)

$1.00\ g\ C_6H_{12}O_6 \rightarrow 0.00555\ moles$

1 mole of $C_6H_{12}O_6$ is produced from 6 moles CO_2 (1)

0.00555 moles $C_6H_{12}O_6$ is produced from 0.0333 moles CO_2

$PV = nRT$

$V = \frac{0.0333\ mols \times 0.0820578\ L\ atm\ mol^{-1}\ K^{-1} \times 298\ K}{1.0\ atm}$ (2)

$= 0.81\ L$ (1)

3) An equimolar (same number of moles) mixture of gaseous methane (CH_4) and propane (C_3H_8) is trapped in a container of fixed volume at constant temperature.

a) Is the average kinetic energy of methane greater than, less than, or equal to, the average kinetic energy of propane? Briefly explain your answer. **(4 points)**

Equal to. (2)
Average KE depends on T not mass. Since T is the same for both CH_4 & C_3H_8, average KE of both are the same (2)

b) Is the partial pressure of methane greater than, less than, or equal to, the partial pressure of propane? Briefly explain your answer. **(4 points)**

Same (2)
Equimolar ⇒ equal mole fraction
mole fraction ∝ partial pressure
Hence, partial pressure same (2)

c) If the container develops a very small leak, allowing the trapped gases to effuse out, would you expect the composition of escaped gas to be richer in methane or propane? Briefly explain your answer. **(4 points)**

Methane (2)
Rate of effusion $\propto \frac{1}{\sqrt{mass}}$
Since CH_4 is lighter, it effuses out faster (2)

4) Why does it take longer to cook a hard-boiled egg in Denver, the "mile-high city" (~5300 feet above sea level) than it does in New York City? **(6 points)**

Liquid boils when vapor pressure equals atmospheric pressure. Atmospheric pressure in Denver is lower than that in NYC. Water boils at a lower temperature in Denver than in NYC since in Denver a lower vapor pressure is required, and hence lower temperature for vapor pressure to equal atmospheric pressure. Since water boils at a lower temp, it takes longer to cook at a lower temp compared to a higher temp.

5) For each of the following which would be a better solvent, water (H_2O) or carbon tetrachloride (CCl_4)? **For each, briefly explain your choice of solvent.**

a) NH_3 – Water (1) **(3 points)**

NH_3 is polar, H_2O is polar. Polar dissolves in polar (2)

hence H_2O is a better solvent for NH_3

b) HCl – polar. (1) H_2O is a better solvent **(3 points)**

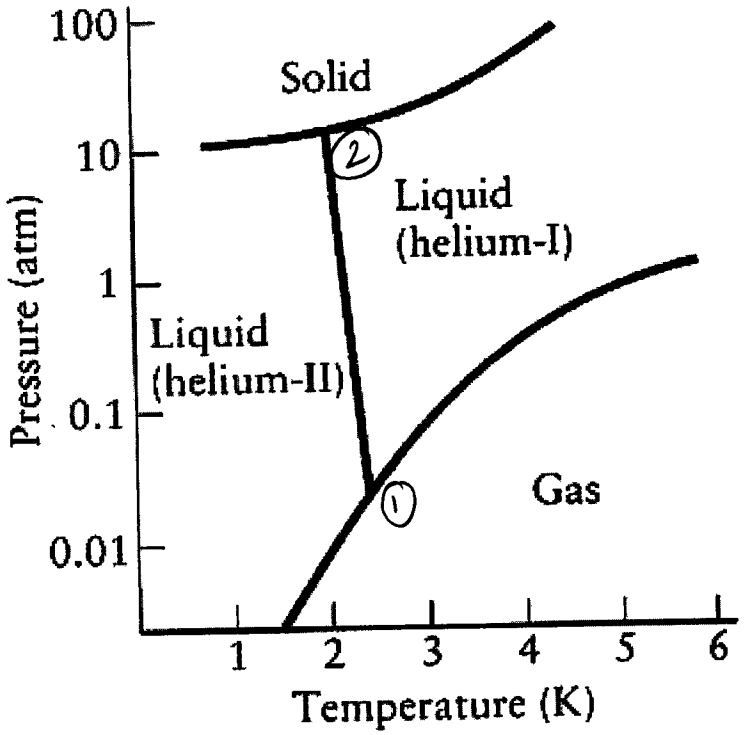
(2)

c) I_2 non polar. Hence non polar CCl_4 (1) **(3 points)**

is a better solvent. Non polar dissolves easier in a (2)

non polar solvent

6) The phase diagram for Helium, He, is shown below. As can be seen from this phase diagram, two phases of liquid He exists, helium –I and helium- II. Helium is the only substance known to have two liquid phases.



Use the phase diagram of He to answer the following questions:

a) What is the maximum temperature at which helium-II can exist? **(3 points)**

~2.5K

b) What is the minimum pressure at which solid helium can exist? **(3 points)**

~ 10 atm

c) What is the normal boiling point of helium-I? **(3 points)**

~5.5K

d) Can solid helium sublime? **(3 points)**

No

e) Describe the phases in equilibrium at each of helium's triple points? **(3 points)**

At ① – Helium II, Helium I, gas 1.5

At ② – Helium II, Helium I, solid 1.5

f) Which liquid phase is more dense, helium-I or helium-II? Explain your answer. **(5 points)**

Helium I ③

Density is mass/volume. Mass is independent of pressure, while volume decreases with increase in pressure. The liquid that exists at higher pressures will have the smaller volume and hence greater density. ②

7) A sample of 2.00 millimoles Cl_2 was sealed into a 2.00 L reaction vessel and heated to 1000 K to study its dissociation into Cl atoms

$Cl_2(g) \leftrightarrow 2\,Cl(g)$ $\quad K = 1.2 \times 10^{-7}$ at 1000 K

The value of K given holds for concentrations expressed as moles L^{-1}

7a) Calculate the equilibrium composition of the mixture expressing the concentration of each component present in the equilibrium mixture as moles L^{-1}. **(8 points)**

$$K = \frac{[Cl]^2}{[Cl_2]} \quad (2)$$

	$Cl_2(g)$	$\rightleftharpoons$	$2\,Cl(g)$
initial	$\frac{2.00 \times 10^{-3}\ mols}{2.00\ L} = 1.00 \times 10^{-3}\ M$		0
change	$-x$		$2x$
equilibrium	$1.00 \times 10^{-3} - x$		$2x$

(2)

$$K = 1.2 \times 10^{-7} = \frac{(2x)^2}{1.00 \times 10^{-3} - x}$$

$$1.2 \times 10^{-10} - 1.2 \times 10^{-7} x = 4x^2$$

$$4x^2 + 1.2 \times 10^{-7} x - 1.2 \times 10^{-10} = 0$$

$$x = \frac{-1.2 \times 10^{-7} \pm \sqrt{(1.2 \times 10^{-7})^2 - 4(4)(-1.2 \times 10^{-10})}}{8}$$

$$= \frac{-1.2 \times 10^{-7} \pm \sqrt{1.44 \times 10^{-14} + 19.2 \times 10^{-10}}}{8}$$

$$x = \frac{-1.2 \times 10^{-7} \pm 4.4 \times 10^{-5}}{8} = 5.5 \times 10^{-6}$$

(2)

At equilibrium $[Cl_2] = 9.9 \times 10^{-4}\ M$ (1) $\quad [Cl] = 1.1 \times 10^{-5}\ M$ (1)

7b) In (a) determine the percentage decomposition of the $Cl_2(g)$ at 1000 K **(7 points)**

% decomposition = $\frac{\text{amount decomposed}}{\text{original amount}} \times 100\%$

$= \frac{5.5 \times 10^{-6}}{0.00100} \times 100\%$

$= 0.55\%$

(5) (2)

7c) Consider the reaction $F_2(g) \leftrightarrow 2F(g)$. At 1000 K the equilibrium constant for this reaction is 1.2×10^{-4}. At 1000K, which is more stable relative to its atoms, Cl_2 or F_2? Explain your answer. **(5 points)**

At 1000K the equilibrium constant for dissociation of F_2 to F atoms is larger than that for the dissociation of Cl_2 to Cl atoms. This indicates that at 1000K more F_2 will dissociate to F atoms that Cl_2 to Cl atoms. Hence Cl_2 is more stable relative to its atoms, than F_2 at 1000K

8) The four gases NH_3, O_2, NO, and H_2O are mixed in a reaction vessel and allowed to reach equilibrium in the reaction. The result is an **endothermic** reaction:

$$4\ NH_3(g) + 5\ O_2\ (g) \leftrightarrow 4\ NO\ (g) + 6\ H_2O(g)$$

a) Certain changes (see below) are then made to this mixture. Considering each separately, state the effect (increase, decrease, or no change) that the change has on the original equilibrium values of the quantity in the second column. The temperature and volume are kept constant.

Change	**Quantity**	
Add NO	amount of H_2O	**(2 points)**
	decrease	
Add NO	amount of O_2	**(2 points)**
	increase	
Add NH_3	equilibrium constant, K	**(2 points)**
	no change	
Remove NO	amount of NH_3	**(2 points)**
	decrease	

b) What effect does a decrease in the volume of the reaction mixture have on the position of the equilibrium of the above reaction. Temperature is held constant. **(2 points)**

#1 gas phase mols in reactants < #1 gas phase mols in products
Decrease in volume favors direction in which fewer gas phase mols ⇒ equilibrium shifted to the left

f) What effect does raising the temperature have on the position of the equilibrium of the above reaction. **(2 points)**

Endothermic reaction
Hence raising temp favors products
Equilibrium shifts to the right.

9) a) Intravenous medications are often administered in 5.0% glucose ($C_6H_{12}O_6$) by mass. What is the osmotic pressure of such solutions at 37°C (body temperature)? Assume that the density of the solution at 37°C is 1.0 g/cm^3. **(5 points)**

5.0% glucose by mass

5g glucose in 95g H_2O

5g glucose $\equiv$ 0.028 moles

$$\text{Molarity} = \frac{0.028 \text{ mols glucose}}{\frac{100.0 \text{ g } H_2O}{1.0 \text{ g/cm}^3 \times 1000 \text{ cm}^3/\text{L}}} = 0.28 \text{ M}$$ (3)

$$\Pi = 0.28 \frac{\text{mols}}{\text{L}} \times 0.0820578 \text{ L atm mol}^{-1}\text{K}^{-1} \times 310 \text{ K}$$ (2)

$$= 7.1 \text{ atm}$$

b) Based on your answer in (a) estimate the osmotic pressure of blood. Explain how you came to your answer. **(5 points)**

osmotic pressure of blood must be ≈ 7.1 atm if it was less than 7.1 atm or greater than 7.1 atm, the cells in the blood will be damaged.