1. °C Hydrogen sulfide (H_2S) gas has a reported solubility of 1.85×10^{-3} mole fraction and a partial partial pressure of 1 atm in water at 25 C. Assuming the solution has a density of $1.0\,\frac{g}{mL}$, calculate the Henry's Law constant k_H for H_2S at 25 C in units of $\frac{mol}{L \cdot atm}$.

$$\chi_{H_2S} = 1.85 \times 10^{-3}\,\text{mol } H_2S/\text{mol total}$$

Assume 100 mol of solution:

$$n_{H_2S} = (1.85 \times 10^{-3}\,\tfrac{mol}{mol})(100\text{ mol}) = 0.185\,\text{mol}$$
$$n_{H_2O} = 100\text{ mol} - 0.185\text{ mol} = 99.815\,\text{mol}$$

Convert to mass:

$$m_{H_2S} = (0.185\text{ mol})(34.08\,\tfrac{g}{mol}) = 6.305\,\text{g}$$
$$m_{H_2O} = (99.815\text{ mol})(18.02\,\tfrac{g}{mol}) = 1{,}796.7\,\text{g}$$

Total mass:

$$m_{\text{total}} = 6.305\,\text{g} + 1{,}796.7\,\text{g} = 1{,}803\,\text{g}$$

Total volume (density $= 1.0\,\frac{g}{mL}$):

$$V = \frac{1{,}803\,\text{g}}{1.0\,\frac{g}{mL}} = 1{,}803\,\text{mL} \cdot \frac{1\,\text{L}}{1{,}000\,\text{mL}} = 1.803\,\text{L}$$

Solubility:

$$s = \frac{0.185\,\text{mol}}{1.803\,\text{L}} = 0.1026\,\frac{mol}{L}$$

Henry's constant:

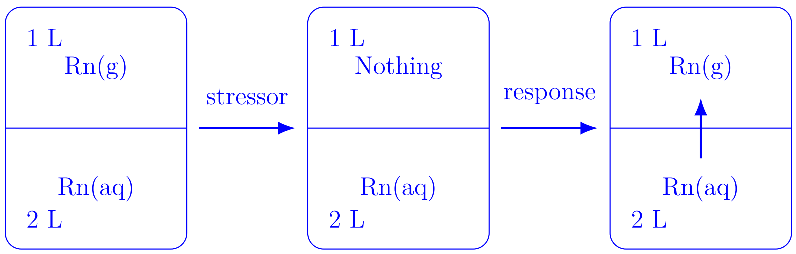
$$k_H = \frac{s}{P_{H_2S\,(g)}} = \frac{0.1026\,\frac{mol}{L}}{1\,\text{atm}} = \boxed{0.103\,\frac{mol}{L \cdot atm}}$$

2. (a) 2.0 L of water is added to a 3.0 L rigid container. Radon gas is added until the system has reached equilibrium at 298 K and the pressure of radon reads 4 bar. Write out a chemical equilibrium between gas and aqueous phase to show the Henry's Law equilibrium, and show that $K = k_H$ with different units. Radon $k_H^\circ = 9.3 \times 10^{-3}\,\frac{mol}{L \cdot bar}$

$$\text{Rn (g)} \rightleftharpoons \text{Rn (aq)} \qquad K = \frac{[\text{Rn (aq)}]}{P_{\text{Rn (g)}}}$$

$$s = k_H P_{\text{Rn (g)}}$$
$$k_H = \frac{s}{P_{\text{Rn (g)}}} = \frac{[\text{Rn (aq)}]}{P_{\text{Rn (g)}}}$$
$$\boxed{k_H = K}$$

(b) All the radon gas is removed from the container and replaced by air. The system is re-establishes equilibrium at 298 K. What is the partial pressure of radon in the vessel at this new equilibrium? A picture can help understand what physical process is occurring.



After the radon gas is removed, the equilibrium will shift as some of the aq will go to the gas phase, but the K is preserved as the temperature remains constant. Based on part a, $K = k_H$, so write an ICE table.

$$\mathrm{Rn\,(g)} \rightleftharpoons \mathrm{Rn\,(aq)}$$

$$s = k_H P$$

$$\frac{n}{2.0\,\mathrm{L}} = (9.3 \times 10^{-3}\,\tfrac{\mathrm{mol}}{\mathrm{L \cdot bar}})(4.0\,\mathrm{bar})$$

$$n = (9.3 \times 10^{-3}\,\tfrac{\mathrm{mol}}{\mathrm{L \cdot atm}})(4.0\,\mathrm{atm})(2.0\,\mathrm{L})$$

$$n = 0.0744\,\mathrm{mol}$$

ICE table in mols

	Rn (aq)	Rn (g)
I	0.0744	0
C	$-x$	$+x$
E	$0.0744 - x$	x

$$K = k_H = \frac{[\mathrm{Rn\,(aq)}]}{P_{\mathrm{Rn\,(g)}}}$$

$$9.3 \times 10^{-3} = \frac{\frac{0.0744 - x}{2.0\,\mathrm{L}}}{\frac{x \cdot 0.08314\,\frac{\mathrm{L \cdot bar}}{\mathrm{mol \cdot K}} \cdot 298\,\mathrm{K}}{1.0\,\mathrm{L}}}$$

$$0.2304x = \frac{0.0744 - x}{2.0}$$

$$1.4608x = 0.744$$

$$x = 0.051\,\mathrm{mol}$$

$$P_{\mathrm{Rn\,(g)}} = \frac{(0.051\ \mathrm{mol})(0.08314\,\frac{\mathrm{L \cdot bar}}{\mathrm{mol \cdot K}})(298\,\mathrm{K})}{1.0\,\mathrm{L}}$$

$$= \boxed{1.262\,\mathrm{atm}}$$

3. A solid has a density of $5.3\,\mathrm{g/cm^3}$ while its liquid phase has a density of $5.6\,\mathrm{g/cm^3}$. Circle the statements that describe the change(s) that the substance would undergo in response to a decrease in external pressure.

- ☐ The freezing point of the liquid will decrease
- ■ The melting point of the solid will increase
- ☐ The boiling point of the liquid will increase
- ■ The condensation point of the gas will decrease
- ☐ The intermolecular forces of the liquid phase will increase

Homework Problem 27

1.

$$AgBr(s) + 2\,S_2O_3{}^{2-}(aq) \rightleftharpoons [Ag(S_2O_3)_2]^{3-}(aq) + Br^-(aq) \quad K = 15$$

You want to dissolve 15 g of AgBr by adding sodium thiosulfate pentahydrate ($Na_2S_2O_3 \cdot 5\,H_2O$) to water. What is the minimum mass of $Na_2S_2O_3 \cdot 5\,H_2O(s)$ that must be added to 500 mL of water in order to ensure that all 15 g of AgBr will dissolve at equilibrium?