6. (a) Metal carbonates react with acids to form a metal salt, carbon dioxide, and water. Acid rain, which contains sulfuric acid, will react with the limestone (calcium carbonate) to produce calcium sulfate, carbon dioxide, and water according to the following reaction.

$$H_2SO_4(aq) + CaCO_3(s) \rightarrow CaSO_4(s) + CO_2(g) + H_2O(l)$$

(b) (i) Impurities (solutes) added to a solvent (water) will always elevate the boiling point of the pure solvent according to the equation $\Delta T = K_b m_{solute}$ (where ΔT is the increase in boiling point from the normal boiling point of the pure solvent, K_b is a constant that is a characteristic of the solvent, and m is the molality of the solute in solution). This is because impurities lower the vapor pressure of a liquid due to interparticular attractions between the solute particles and solvent particles. Since the vapor pressure of a liquid increases with temperature, and boiling occurs when the vapor pressure equals the atmospheric pressure, a higher temperature for the liquid will be required for this equality to be reached. Boiling point is the temperature at which this equality is achieved so the boiling point of the solvent will be elevated by the addition of either of these solutes.

(ii) NaCl ionizes in water into two particles (Na^+ and Cl^-), whereas sugar ($C_{12}H_{22}O_{11}$) is nonionizing and so dissolves as one particle. The equation in 6. (b) (i) above is modified to $\Delta T = iK_b m_{solute}$ (where i is the van't Hoff factor, defined as $i = \dfrac{\text{moles of particles in solution}}{\text{moles of solute dissolved}}$).

The van't Hoff factor for sodium chloride is approximately 2 (not exactly 2 due to ion pairing), while the van't Hoff factor for sugar is one. Therefore, with equal concentrations of solute (0.10 M) the boiling point elevation for salt (NaCl) will be greater than that of sugar.

(c) At low temperatures, the gas sis moving so slowly that intermolecular attractions play a significant role. These attractive forces (which are relatively weak for methane since it is a nonpolar gas) are not significant at ordinary temperatures because the molecules are moving very fast compared to at low temperatures. At low temperatures, the molecules will be pulled closer together by these attractive forces and the volume of the gas will be less than expected by the ideal gas law equation (PV = nRT) at a given temperature and pressure. A similar effect occurs when the gas is at high pressures because at these pressures, the molecules are pushed close together so the intermolecular attractive forces become significant resulting in smaller-than-expected volumes.

(d) Water vapor molecules in the air is moving too fast for the their intermolecular attractions to effect significant condensation. However, when they strike the surface of the cold glass of the beaker of ice bath, much of their kinetic energy is given to the cold glass (containing lower energy). This reduction in the kinetic energy of the water vapor molecules means that they are moving much slower than before the collision with the cold glass. The intermolecular attractions of the vapor molecules are strong enough to form intermolecular bonds and, thus, condense at these slower speeds.

8. (a) (i)

```
        H     O     H
        |     ||    |
    H — C  —  C  —  C — H
        |           |
        H           H
```
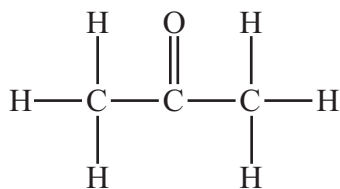
   Propanone

   (ii) $109°$

(b) (i) Propane is very nonpolar because its structure is very symmetrical. Therefore, it does not have very strong intermolecular bonds holding the molecules together in the liquid state and is easily vaporized (low $\Delta H°_{vap}$). Propanone is not as symmetrical as propane and has a very electronegative oxygen atom that has a stronger pull for the shared electrons than the rest of the atoms in the molecule. This make the portion of the molecule with the oxygen atom more negative than the rest of the molecule. Since that makes this molecule somewhat polar, it will be harder for propanone molecules to break the intermolecular bonds in the liquid state to form independent vapor molecule. Thus, propanone will have a somewhat higher $\Delta H°_{vap}$.

   (ii) The double bond on the oxygen in the propanone makes the electrons between the oxygen atom and the carbon atom to which it is bonded more localized (held tighter between these two atoms) than the electrons between the oxygen atom and the carbon atom in the 1-propanol molecule. This makes the 1-propanol molecule more polar, thus, stronger intermolecular attractions, Therefore, harder to vaporize by breaking these intermolecular bonds in the liquid phase to become independent vapor molecules. As a result, a higher $\Delta H°_{vap}$.

(c)

```
        H           H     H
        |           |     |
    H — C  —  O  —  C  —  C — H
        |           |     |
        H           H     H
```
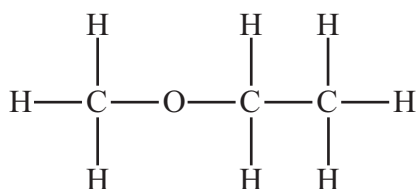
   Methyl ethyl ether

(d) (i) sp
   (ii) There are five sigma (σ) bonds (four C--H sigma bonds and one C--C sigma bonds) and two pi (π) bonds (both between the two carbon atoms).

1. (a) (i) $AgCl(s) \rightleftharpoons Ag^+(aq) + Cl^-(aq)$
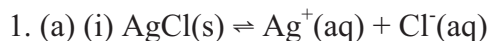
(ii) ? mole $AgCl(s) = 8.9 \times 10^{-5}$ g $\left(\dfrac{1 mole AgCl(s)}{107.87 g AgCl(s)} \right) = 8.3 \times 10^{-7}$ moles $AgCl(s)$

? molarity $= \left(\dfrac{moles of solute}{L of solution} \right) = \left(\dfrac{8.3 x 10^{-7}}{0.100 L solution} \right) = \boxed{8.3 \times 10^{-6} \text{ M} = \text{solubility of AgCl at } 10°C}$

(iii) $K_{sp} = [Ag^+][Cl^-] = (8.3 \times 10^{-6} \text{ M}) \cdot (8.3 \times 10^{-6} \text{ M})$

$\boxed{K_{sp} = 6.8 \times 10^{-11}}$

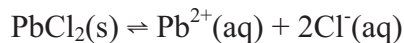(b) (i) molarity $= \left(\dfrac{moles of solute}{L of solution} \right)$

0.0400 M $Cl^- = \left(\dfrac{\# moles of Cl^-}{0.0600 L solution} \right)$ 0.0300 M $Pb^{2+} = \left(\dfrac{\# moles of Pb^{2+}}{0.0600 L solution} \right)$

\# moles $Cl^- = 0.00240$ moles Cl^- \# moles $Pb^{2+} = 0.00180$ moles Pb^{2+}

Total volume of solution $= 60.0$ mL $+ 60.0$ mL $= 120.0$ mL

? M $Cl^- = \left(\dfrac{0.00240 moles Cl^-}{0.1200 L solution} \right)$? M $Pb^{2+} = \left(\dfrac{0.00180 moles Pb^{2+}}{0.1200 L solution} \right)$

? M $Cl^- = 0.0200$ M Cl^- ? M $Pb^{2=} = 0.0150$ M Pb^{2+}

$PbCl_2(s) \rightleftharpoons Pb^{2+}(aq) + 2Cl^-(aq)$
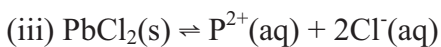
$K_{sp} = [Pb^{2+}][Cl^-]^2 = 1.6 \times 10^{-5}$

$Q = [Pb^{2+}][Cl^-]^2 = (0.0150 \text{ M}) \cdot (0.0200 \text{ M}) = 6.00 \times 10^{-6}$

$\boxed{\text{Since Q is smaller than } K_{sp}, \text{ there will be no precipitate.}}$

(ii) $K_{sp} = [Pb^{2+}][Cl^-]^2$

$1.6 \times 10^{-5} = [Pb^{2+}](0.25 \text{ M})^2$

$\boxed{[Pb^{2+}] = 2.6 \times 10^{-4}}$

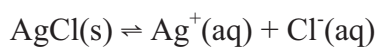(iii) $PbCl_2(s) \rightleftharpoons P^{2+}(aq) + 2Cl^-(aq)$ $AgCl(s) \rightleftharpoons Ag^+(aq) + Cl^-(aq)$

$K_{sp} = [Pb^{2+}][Cl^-]^2$ let x $= [Pb^{2+}]$ $K_{sp} = [Ag^+][Cl^-]$ let x $= [Ag^+]$

$1.6 \times 10^{-5} = (x) \cdot (2x)^2$ $1.8 \times 10^{-10} = x \cdot x$

$x = [Pb^{2+}]_{max} = 0.0159$ M $x = [Ag^+] = 1.34 \times 10^{-5}$ M

so 2x $= [Cl^-] = 0.0318$ M   so x $= [Cl^-] = 1.34 \times 10^{-5}$ M

$\boxed{\text{Therefore, AgCl(s) will precipitate first since it requires the smallest concentration } (1.34 \times 10^{-5} \\ \text{M}) \text{ to precipitate.}}$

5. (a) Solution 1 [Pb(NO$_3$)$_2$] will have the highest boiling point because it produces the most ions (one Pb^{2+} ions and two NO$_3^-$ ions for each formula species). The boiling point of water increases according to the equation $\Delta T = iK_b m_{solute}$, where i (the van't Hoff factor) indicates the number of particles in solution.

   (b) Solution 5 [KC$_2$H$_3$O$_2$] will have the highest pH because the acetate ion (C$_2$H$_3$O$_2^-$) will react with the hydrogen ion (H$^+$) to form acetic acid, thus, reducing the concentration of the hydrogen ion and raisng the pH.

   (c) Solution 1 [Pb(NO$_3$)$_2$] and solution 2 [NaCl] will form PbCl$_2$(s) when mixed.

   (d) None of these solutions could be used to oxidize the Cl$^-$(aq) ion.

   (e) Solution 4 is the least effective conductor of electricity because it is the only solution that does not consist of an ionic material, but rather is a molecular solution.

1. (a) $$K_C = \dfrac{[H_2]^2[S_2]}{[H_2S]^2}$$

(b) (i) ? moles $H_2S = 3.40$ g $H_2S\left(\dfrac{1\, mole\, H_2S}{34.1\, g\, H_2S}\right) = 0.0997$ moles H_2S

$$\text{Molarity} = \frac{moles\, of\, solute}{volume\, of\, solution} = \frac{0.0997\, moles\, H_2S}{1.25L} = 7.98 \times 10^{-2}\ M\ H_2S$$

$$\text{Molarity} = \frac{moles\, of\, solute}{volume\, of\, solution} = \frac{3.72 x 10^{-2}\, moles\, S_2}{1.25L} = 2.98 \times 10^{-2}\ M\ S_2 = x$$

$[H_2] = 2x$ (from mole ratio in balanced equation $= 2(2.98 \times 10^{-2}\ M) = 5.96 \times 10^{-2}\ M$

$$[H_2] = 5.96 \times 10^{-2}\ M$$

(ii) $[H_2S] = 7.98 \times 10^{-2} - 2x$ (from mole ratio in balanced equation $= 7.98 \times 10^{-2}\ M - 2 \cdot (2.98 \times 10^{-2}\ M)$

$$[H_2S] = 2.02 \times 10^{-2}\ M$$

(c) $$K_C = \frac{[H_2]^2[S_2]}{[H_2S]^2} = \frac{(5.96 x 10^{-2})^2 (2.98 x 10^{-2})}{(2.02 x 10^{-2})^2}$$

$$K_C = 0.259 = 2.59 \times 10^{-1}$$

(d) $P_{S_2}V = n_{S_2}RT$

$$P_{S_2}(1.25L) = (2.98 x 10^{-2}\, mol)\left(0.0821\frac{L \bullet atm}{K \bullet mol}\right)(483K)$$
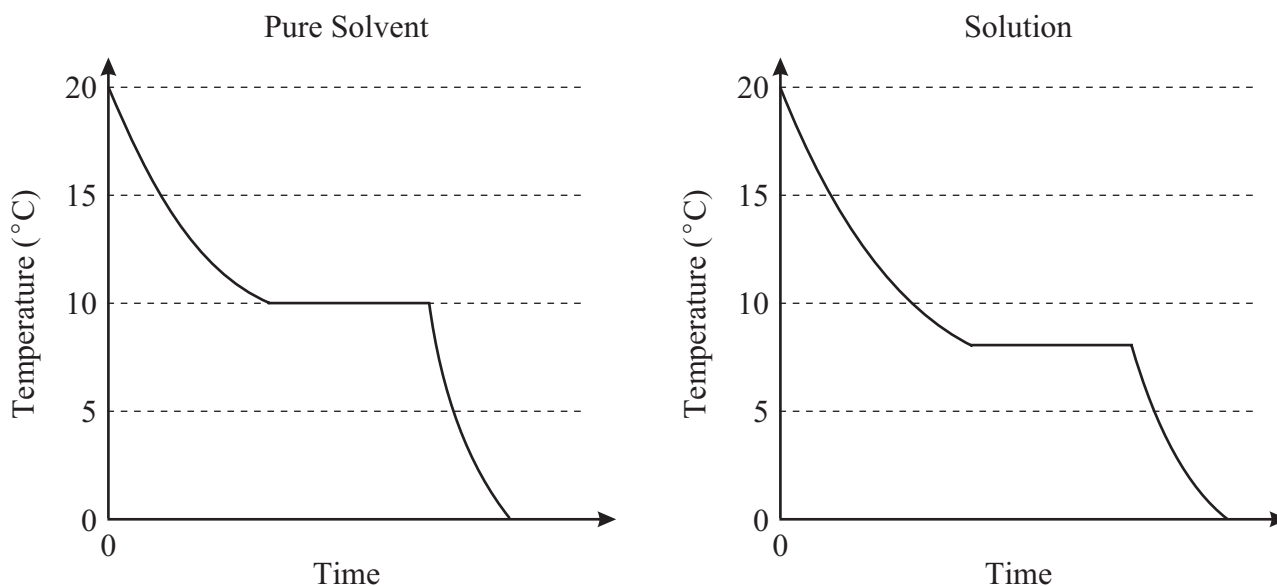
$$P_{S_2} = 0.945\ atm$$

(e) $$K_C = \frac{1}{\sqrt{K_{C_F}}} = \frac{1}{\sqrt{4.23 x 10^{-2}}}$$

$$K_C = 4.86$$

Organization of Data

	H$_2$S (g)	H$_2$ (g)	S$_2$ (g)
Initial	7.98 x 10^{-2}	0	0
Change	7.98 x 10^{-2} - 2x	2x	x
Equilibrium	2.02 x 10^{-2}	5.96 x 10^{-2}	2.98 x 10^{-2}

5. (a)

Pure Solvent

Solution

(b) (i) The mass of the pure solvent used and the mass of the unknown solid ($m_{measured}$) added to this solvent to make the solution to be tested.

(ii) $\Delta T = K_f m_{solute}$

$m_{solute} = \dfrac{n_C}{mass(kg)solvent}$ (n_C - calculated number of moles of solute-from definition of molality)

? g solute $= 1$ mole solute $\left(\dfrac{m_{measured}}{n_C} \right)$

(iii) The graphs can be used to determine the ΔT of the freezing point as a result of putting the unknown solid into the solvent. This ΔT is the difference in temperature where the horizontal portions of the graph appear. These horizontal portions represent the time during which freezingis occuring (the temperature remains a constant during a phase change).

(c) Evaporation of the solvent will cause the actual concentration of the solute to increase. This effect will cause the freezing point to depress further than before evaporation which will result in a perceived in crease in ΔT, thus m_{solute}. From the calcuations that are set up in (b.) ii. above, the perceived increase in m_{solute} will result in a higher n_C value and ,ultimately, a smaller molar mass.

(d) % error $= \left(\dfrac{|ActualValue - ExperimentalValue|}{ActualValue} \right) x100\% = \left(\dfrac{|120g/mol - 126g/mol|}{120g/mol} \right) x100\%$