**Problem #8 (7 points)**

(a) Lead chloride dissolves in water according to

$$PbCl_2(s) = Pb^{2+}(aq) + 2\,Cl^-(aq)$$

The solubility in pure water has been measured to be 4.44 g $L^{-1}$. Calculate the solubility product of lead chloride in pure water.

3

$4.44\ g\ PbCl_2/L = 4.44/(207.2+35.45+35.45) = \frac{4.44}{278.1}$

$= 1.60\times10^{-2}\ M$

$PbCl_2 = Pb^{2+}_{(aq)} + 2Cl^-_{(aq)}$

$[Pb^{2+}] = c_s$ and $[Cl^-] = 2c_s$

$\therefore K_{sp} = [Pb^{2+}][Cl^-]^2 = (c_s)(2c_s)^2 = 4c_s^3$

$= 4(1.60\times10^{-2})^3 = 1.64\times10^{-5}$

(b) Calculate the solubility of lead chloride in a $3.091 \times 10^{-4}$ *M* potassium chloride (KCl) solution. Express your answer in moles $PbCl_2$ per liter of solution (*M*). Regardless of what answer you obtained in part (a), in this calculation use the value of $3.091 \times 10^{-5}$ for $K_{sp}$ of lead chloride.

4

$3.091\times10^{-4}\ M\ KCl \Rightarrow 3.091\times10^{-4}\ M\ Cl^-_{(aq)}$

but this is much less than $[Cl^-]$ from simple dissociation of $PbCl_2$ in pure water

$\therefore$ expect common ion effect to be negligible

$\therefore$ no change from part (a)

$\Rightarrow c_s = 4.44\ g/L$

---

check using common ion effect calculation

$c_s = [Pb^{2+}] = \frac{K_{sp}}{[Cl^-]} = \frac{1.64\times10^{-5}}{(3.091\times10^{-4})^2} = 1.72\times10^{2}$ !!

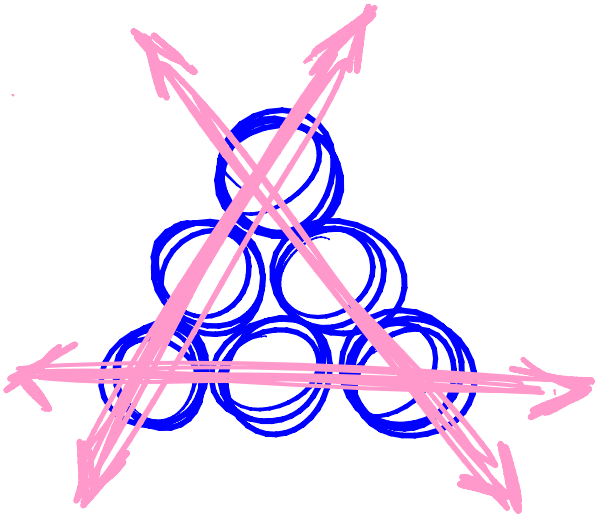
impossible

from KCl

**Problem #9 (8 points)**

(a) Sketch a fragment of the (111) plane in gold (Au) to show the arrangement of atoms which are to be represented as hard spheres. Show at least six atoms.

2



slip occurs along <111>

(b) On the sketch you have drawn in answer to part (a), label all directions in which slip occurs.

3 see above

(c) Calculate the atomic packing density in the (111) plane of gold (Au). Express your answer in units of atoms $cm^{-2}$.

3 Au is FCC so use $\frac{4}{a^3} = \frac{N_{AV}}{V_{molar}}$

$$\Rightarrow a = \left(\frac{4\,V_{molar}}{N_{AV}}\right)^{1/3} = \left(\frac{4\times 10.2}{6.02\times 10^{23}}\right)^{1/3} = 4.08\times 10^{-8}\ cm$$
$$= 4.08\ \text{Å}$$

in FCC, $a = 2\sqrt{2}\,r \Rightarrow a^2 = 8r^2$

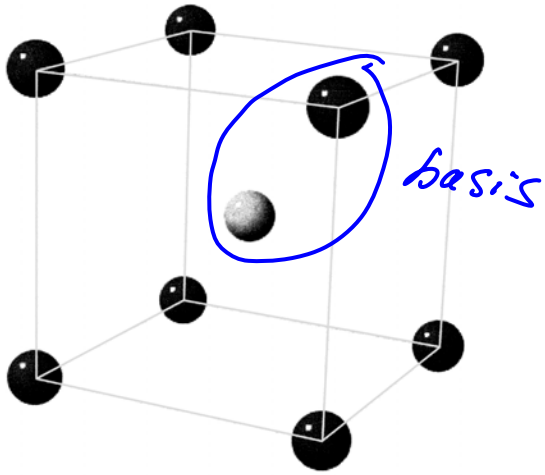
area of $\Delta = \frac{1}{2}bh = \frac{1}{2}(4r)(4r\sin 60)$

$$= 8r^2(0.866) = 0.866\,a^2$$

no. atoms in $\Delta = (3\times\tfrac{1}{2}) + (3\times\tfrac{1}{6}) = 3/2 + 1/2 = 2$

$$\Rightarrow \text{atom density} = \frac{2}{0.866\,a^2} = 1.39\times 10^{15}\ \text{atoms}/cm^2$$

## Problem #10 (3 points)




The crystal structure of cesium chloride (CsCl) is shown in the adjacent figure. The dark spheres represent atoms of Cl.

(a) Identify the crystal system.

cubic

(b) Identify the Bravais lattice.

simple cubic

(c) Identify the basis of the crystal structure.

$Cs^+$ & $Cl^-$ ion pair

## Problem #11 (6 points)

(a) Comment on the solubility of hydrogen ($H_2$) in liquid ammonia ($NH_3$). State whether you expect hydrogen to be ***highly soluble*** or ***almost insoluble***, and explain why.

- almost insoluble
- $H_2$ is a homonuclear molecule, ∴ nonpolar, ∴ only van der Waals bonding operative between $H_2$ molecules
- $NH_3$ is polar and in addition possesses hydrogen-bonding capability
- dissimilarity in available intermolecular bonding leads to poor solubility

(b) Comment on the solubility of potassium iodide (KI) in liquid iodine ($I_2$). State whether you expect potassium iodide to be ***highly soluble*** or ***almost insoluble***, and explain why.

- almost insoluble
- KI is ionic and therefore soluble in either an ionic liquid or a liquid that is strongly polar
- $I_2$ is a homonuclear molecule, ∴ nonpolar, ∴ only van der Waals bonding operative between $I_2$ molecules
- dissimilarity in available intermolecular bonding leads to poor solubility

## Problem #12 (9 points)

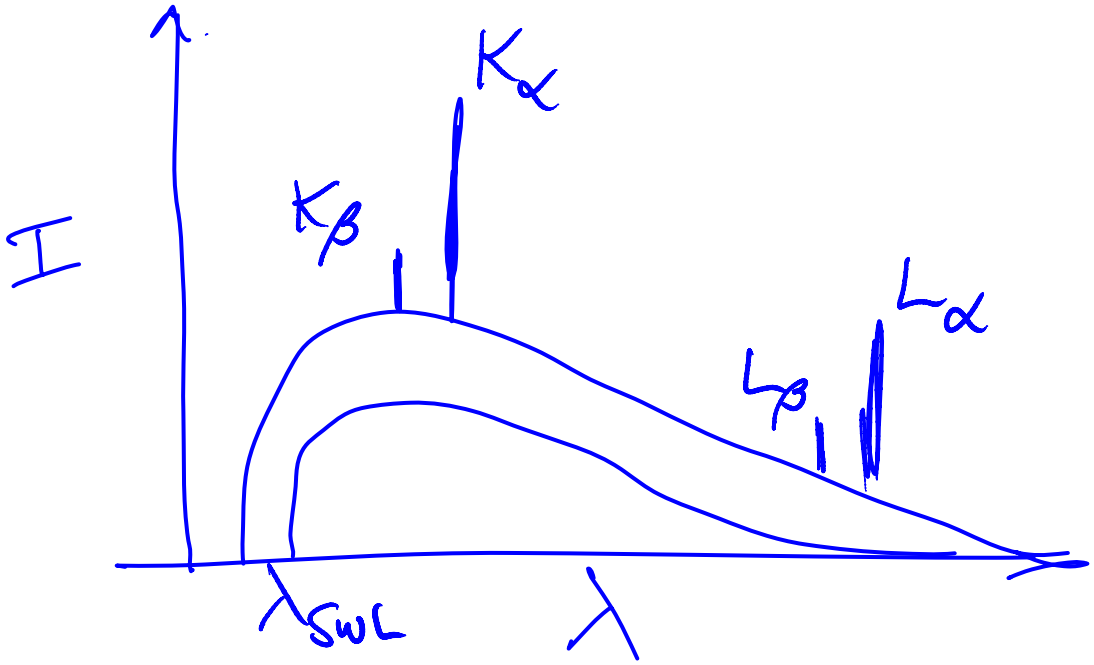
(a) The beryllium window in your x-ray generator must be replaced but the manufacturer reports that it will be months before you can expect delivery. For suggestions you turn to the two UROPs working for you. One recommends that, instead of beryllium, you use diamond. The other recommends barium as an alternative to beryllium. Both materials are easily available. Ignoring cost, which material would make a better x-ray window in the absence of beryllium? Explain your choice.

3

- diamond
- need low atomic number to minimize the number of occupied energy levels which in turn results in minimum amount of absorption of x-radiation through electron excitation in the window

(b) On a plot of ***intensity*** (I) versus ***wavelength*** ($\lambda$) sketch the emission spectrum of an x-ray generator.

3




(c) Explain the origin of the continuous spectrum or *Bremsstrahlung*.

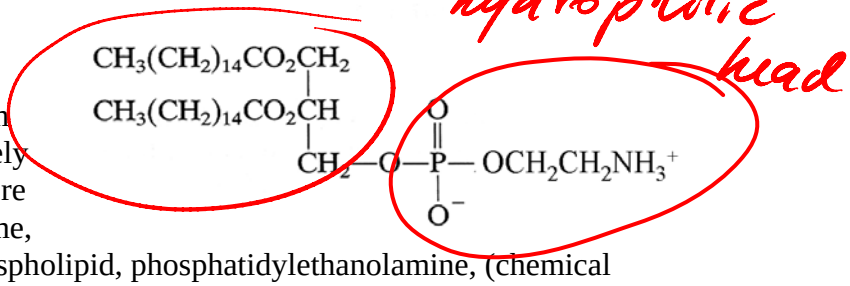
3

- incident electrons in x-ray generator tube change direction under the influence of the repulsive force exerted on them by the electron clouds of atoms in the target
- when charged particles change direction they accelerate which in turn results in a change in energy which in turn results in photon emission
- *Bremsstrahlung* is distribution of emissions from incident electrons whose trajectories have been altered by this interaction
- as the set of all incident paths and thus the set of all scattering angles is continuous, the spectrum is continuous

hydrophobic tail

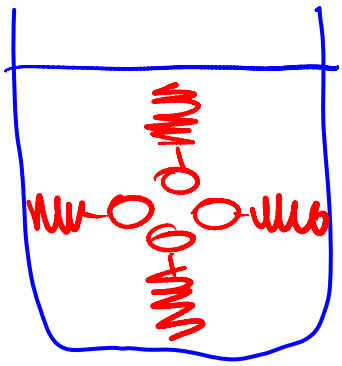
hydrophilic head

**Problem #13 (5 points)**




(a) Carbon tetrachloride ($CCl_4$) is a liquid at room temperature and until the mid 1960s was widely used as a cleaning fluid, both in industry, where it served as a degreasing agent, and in the home, where it was used as a spot remover. The phospholipid, phosphatidylethanolamine, (chemical formula given at right) is added to carbon tetrachloride in sufficient quantity to enable interaction between phospholipid molecules. Draw a cartoon depicting one possible molecular arrangement that results.

2



model the phospholipid as

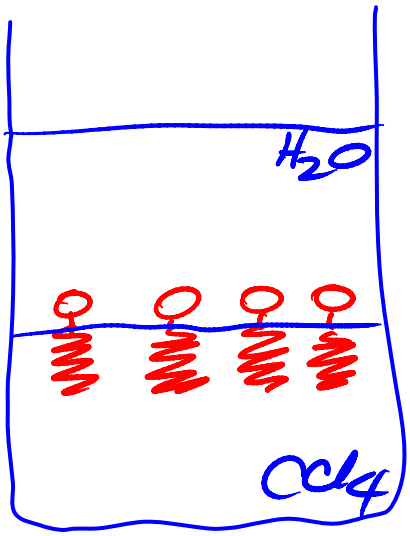
tail head

(see above)

beaker filled with $CCl_4$

(b) To the system described in part (a) an equal volume of water is added. The $H_2O$ - $CCl_4$ mixture containing the phosphatidylethanolamine is then subjected to vigorous agitation for several minutes and then allowed to equilibrate. Draw a cartoon depicting one possible molecular arrangement that results.

3




beaker filled with $H_2O$ & $CCl_4$