Liquid and Solid Jellybean Density

*Sample Theory for Major chem 1114 lab*

Sample Theory: density of liquid and solid jellybeans

# Density

The distribution of the sugar filling of jellybeans in either liquid or solid state is uneven owing to variations in how the beans are made and melted. However, the jellybeans’ liquid and solid densities are expected to each have an *average* density, dav (liq) or dav(solid) which can be taken as representative of the`intensity’ of sugar present in the bean in either phase. Given bean mass, m, and its volume V in either melted or solid form, the dav for either phase can be computed as shown in Equation 1a,b

As asserted in 1, the generally accepted units for density assume m is measured in grams and V measured in cm3 .

1a dav (liq) = mL /VLiq grams/cm3 .

1b dav (solid) ms /Vsolid grams/cm3

These equations approximate the bean filling as homogeneous and invariant. If this can be assumed, the density is an intensive physical constant uniquely characterizing the bean filling , rather like a social security number . At an atomic level, the value of dav is reflective of the individual degree of `packing’ or crowding of sugar molecules in the bean. To determine dav(liq) and dav(solid) accurate determinations of both m and V for the unknown must be made.

###### Calibration of the Jelly Bean Pycnometer

Volume is the more difficult of these two values to determine. Here, I will determine VLiq through use of the `pycnometric’ technique. In this approach water is first used to calibrate the volume of a pycnometer flask. This is accomplished by measuring the mass of the flask empty, mf and again when full of water, mfw . The mass difference, mw = mfw- mf in grams is the mass of water that fills the flask. By re-arranging 1, I can then determine the flask volume, Vf, since the density of water, dw, is estimated as ~ 0.93 g/cm3 at 100oC, which is the temperature of where the measurements will be made.

2 Vf = mw / dw= mw/ 0.93 cm3

liquid jelly bean density determination at 100 oC

Given a value for Vf the value for a jellybean’s dav(liq) can be determined by carefully melting beans at ~ 100 oC and completely filing the calibrated flask volume with the melt at 100 oC. The mass of the melt, mL, is computed given the tare weight of the flask Mf , and the weight of flask and melted beans, Mfb ,as shown in equation 3.

3 mL = Mfb - Mf

Since it is assumed that the bean melt will entirely fill the flask as a homogenous liquid at its melting point of 100 oC,

4 VLiq = Vf

The average liquid jellybean density, dav(liq) can easily be calculated from experimental observables as below:

5 d av (liq) = mL = (mfb – mf ) = (mfb-mf) = 0.93\*(mfb-mf)  g/cm3 at 100oC

Vliq Vf  (mw/0.93) mw

solid jelly bean density determination at 24 oC

Determining the density of the solid jelly beans is a bit more involved, since the beans are irregular in shape and will not in any case entirely fill the pyncnometer. The difficult part is to figure out a bean’s solid volume, Vsolid . This can be accomplished by noting that if we fill the pyncnometer with a combination of beans and water, the water will fill up all the space in the pyncnometer *not* taken up by the beans. Thus:

6 Vf = Vsolid + Vw

Equation 6 can be rearranged to yield Vmetal by difference:

7 Vsolid= Vf – Vw

Since Vf is already known from 2 (assuming that the flask does not change significantly in volume at 100 C vs 24 C), the problem of determining Vsolid reduces to determining the volume of water, Vw  that shares the flask space with the beans. I can accomplish this by first measuring the mass of the flask and solid beans , mfs and then re-measuring the mass of the flask, water and beans after filling the flask with water, mfsw . The difference of the two masses is the mass of the water, mw sharing space with the metal:

*mass of water sharing the pyncnometer space with the solid beans*

7 mw = mfsw- mfs

The corresponding volume of this water in the flask is then ascertained using the density equation for water, 1, rearranged for Vw at 24 C.

*Volume of water sharing the pyncnometer space with the solid beans*

8 Vw = mw/1.000 = (mfsw- mfs)

The related solid bean mass, ms, can now be computed by taking the difference in mfs and the mass of the flask alone, mf, determined previously when measuring the liquid bean density:

9 ms = mfs - mf

Thus, the solid bean density can be computed from observables using the results of equations 6- 9 and weight data as described below:

10 dav(solid) = ms = (mfs – mf) = (mfs – mf)

Vsolid Vf - Vw Vf -(mfsw- mfs)

Notes: *features of Theory* The theoretical relationships between observables (mf etc ) and the desired quantities (dav (solid) & dav(liquid) are laid out. The reasoning and assumptions by which the Purpose is achieved are made painfully explicit. Assumed units, the physical `sense’ of the quantities and appropriate references are clear. Spend signficant effort here ! I read this part most thoroughly. Keep your notation simple and consistent. Avoid putting in any experimental numbers in Theory since you have not- in principle- run the experiment before writing out the Theory. Obvious copying or paraphrasing of the above will result in a fail for the theory.

USE YOUR OWN WORDS !!!!!!