Scale of solids

Definition of bulk density:

In the following we will work more frequently with the term "bulk density". This denotes the density (mass per volume) that a substance assumes when it is present in solid grains. For most solids that are measured with a measuring cup (salt, sugar, rice, flour, etc.), this is the most important quantity when you want to determine how much volume a certain amount is taking up.

1000ml: 30.000 grains rice

The weight of a grain of rice varies between 12mg and 42mg per grain, depending on the variety and harvest, with 22.5mg being the most common[1]. The average bulk density of rice is[2] 0.7kg/l, i.e. one litre of rice weighs 0.7kg or 700,000mg. This brings us to 700000/22.5 = 31,111 grains of rice in 1l of rice. Rounded this results in approx. 30,000 grains of rice.

800ml: 15 USD in 1c pieces

Own measurement, see photo:

[1] https://www.tandfonline.com/doi/pdf/10.1080/00380768.1984.10434709
[2] http://www.mollet.de/info/schuettgutdichte.html

667ml: One million grains of sugar

For this figure we refer to the calculation or measurement by Michael Onken, which he published here in 2001. According to this, 500 ml of sugar contain 750,000 sugar grains, which gives a volume of 667 ml for one million sugar grains.

530ml: One billion grains of flour

For this calculation we first need the size of a flour grain. This of course depends on the type of flour, for simplicity we use wheat flour here, but this also exists in many different varieties. In general: Depending on the definition, a particle size of less than 150-200µm is required for wheat flour, so that this is the maximum size of a flour grain. The actual size is between 60µm and 90µm[3]. For the following calculation we take the mean value between these two sizes of 75µm.
From this we must now calculate the weight of a grain. We approach a flour grain by spherical shape, which results in a volume of 4/3Pi * 37.[53] µm3 = 220893µm3 = 220993*10-12cm3 at a radius of 75/2µm = 37.5µm. Flour essentially consists of starch, which has a density of 1.5g/cm3[4] , resulting in 331489.5*10-12g for a flour grain. One billion grains of flour (1*109) thus weigh approx. 331.5g.
The bulk volume of wheat starch is[5] approx. 0.625g/cm3 , i.e. 625g/l. The result is that 331.5 g flour occupies a volume of 331.5/625 l = 530.4 ml.

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[3] Particle size analysis of two distinct classes of wheat flour by sieving
[4]https://www.caelo.de/getfile.html?type=sdb&num=13
[5]https://www.caelo.de/getfile.html?type=sdb&num=13

391ml: Deadly dose of salt

Usually we speak of a lethal dose when the so-called LD50 dose is reached: This is the amount of the poison that 50% of people die from taking. This information is usually given in milligrams of poison per kilogram of body weight. In practice, experiments are usually carried out with mice and the result is then extrapolated to humans, so that the data are never completely accurate, sensitive people can also die of significantly less.

The LD50 dose for table salt is[6] 4g/kg. If we assume an average body weight of 70kg, we arrive at a dose of 280g. The bulk density of common salt is 735g/l, which brings us to 391ml.

But beware: the so-called LD0 dose is the lowest dose at which poisoning symptoms can already occur. With this dose you only get about 98ml!

286ml: amount of salt in the human body

The human body contains different types of salts, but we will limit ourselves to the normal household salt (NaCl). This is present in the body in dissolved form, i.e. as sodium ions and as chlorine ions. Each of these ions accounts for 0.15%[7], i.e. we arrive at a total of 0.3% NaCl in the human body. With an average human weight of 70kg, we get 0.21kg NaCl in the body. The bulk density of household salt[8] is approx. 735g/l, which means that 210g of salt has a volume of 286ml.

159ml: sugar in a 1,5l bottle Coca-Cola

Coca-Cola contains 10.6g sugar per 100ml[9], that is 159g in 1.5l. The bulk density of household sugar (sucrose) is[10] about 1kg/l, so we get 159ml of sugar.

Scale liquids

1l: Thirty-three quadrillion four hundred and fifty-six trillion water molecules

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[6] http://www.bioshopcanada.com/msds/SOD001.pdf
[7] https://en.wikipedia.org/wiki/Composition_of_the_human_body
[8] http://www.mollet.de/info/schuettgutdichte.html
[9] https://www.coca-cola-deutschland.de/marken/coca-cola/coca-cola
[10] http://www.mollet.de/info/schuettgutdichte.html

To calculate how many water molecules there are in a litre of water, you need the so-called molar mass (unit u): This indicates how heavy a molecule of this substance is and is defined in such a way that NA particles of the substance C12 (carbon of the isotope C12) weigh exactly 12g. NA are exactly 6.022140857*1023 particles. The molar mass of hydrogen can be determined from the fact that water (H2O) consists of two hydrogen atoms and one oxygen atom: Hydrogen has molar mass 1u, oxygen 16u. This results in a weight of 18u for water. 18u correspond to 18/NA grams.
1l water weighs exactly 1000g, so we can calculate the number of water molecules in it by this formula: 1000*NA/18 = 3,34563381*1025 or rounded to 5 digits: Thirty-three quadrillion four hundred and fifty-six trillion.

750ml: kerosene consumption of an A320 at cruising altitude per second

According to Wikipedia, the[11] kerosene consumption of an A320 at cruising altitude is 2700l per hour. This results in a consumption per second of 0.75l.

Of course, the total consumption is higher in practice, as the aircraft needs more kerosene during take-off. To estimate this value, one can look at what Airbus indicates as the total range, tank capacity and maximum speed of an A320[12]:
Total range: 6300km
Tank capacity: 26730l
Maximum speed (MMO): 0.82Mach = 1013 km/h
This results in an estimate of 26730/(6300/1013) litres per hour, which corresponds to 4298l per hour and 1.2l per second.

700ml: volume of half a human brain

Here we refer to the website The Physics Factbook, which answered this question in an exemplary manner: The volume of a human brain is between 1300cm3 to 1500cm3 and thus on average 1400cm3, which corresponds to 1,4l. So half a human brain has a volume of 700ml.

500ml: volume of a human breath

The English Wikipedia has dedicated a separate article to this topic:
https://en.wikipedia.org/wiki/Tidal_volume

[11] https://de.wikipedia.org/wiki/Airbus-A320-Familie#Technische_Data
[12] https://www.airbus.com/aircraft/passenger-aircraft/a320-family/a320neo.html

357ml: Quantity of honey for which a bee has to fly around the earth three times.

According to the German Beekeepers' Association (Imkerbund e.V.), a bee flies 120,000 km on average for 500g of honey[13]. The circumference of the earth is about 40.000km, so that you have to cover 120.000km for three orbits. Honey has a density of[14] approx. 1.4kg/l, i.e. 500g honey have a volume of 357ml.

212ml: Volume of uranium-235 required to generate the yearly electricity demand of a small town by nuclear fission.

By fission of a uranium-235 nucleus, an energy of approximately 190MeV usable in a nuclear power plant is obtained[15]. In 2014, 7035kWh were[16] consumed per inhabitant in Germany. 190MeV correspond to 8.456*10-18 kWh, so one inhabitant needs the energy from the fission of 7035/8.456*10-18 = 8.32*1020 uranium-235 atoms.

A uranium-235 atom weighs 235u, i.e. 235/NA grams (see the 1000ml explanation for details on this calculation). This results in 8.32*1020 uranium-235 atoms weighing 235/NA * 8.32*1020g = 0.325g. So we need 0.325g uranium-235 to produce enough energy for a German for one year.

A small town by definition has[17] between 5000 and 20,000 inhabitants, we take the average of 12,500 inhabitants for simplicity's sake. A small town therefore needs on average per year the energy from nuclear fission of 12500 * 0.325g = 4063g uranium.

uranium has a density of[18] 19.16g/cm3, so 4063g uranium-235 have a volume of 4063/19.16cm3 = 212cm3 = 212ml

In practice, the uranium that is used in nuclear power plants only contains about 5% of the isotope 235, i.[19]e. at least 80 kg is required. Since a modern nuclear power plant only has an efficiency of[20] approx. 35%, in practice we need 80/0.35kg = 229kg uranium per year for our small town. This has a volume of approx. 12l.

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[13] https://deutscherimkerbund.de/161-Imkerei_in_Germany_Facts_figures_data
[14] https://de.wikipedia.org/wiki/Honig#Zusammensetzung
[15] https://de.wikipedia.org/wiki/Kernspaltung#Energiebilanz
[16] https://data.worldbank.org/indicator/EG.USE.ELEC.KH.PC
[17] https://de.wikipedia.org/wiki/Kleinstadt
[18] https://de.wikipedia.org/wiki/Uran
[19] https://de.wikipedia.org/wiki/Uran-Anreicherung#Verwendung_of_the_enriched_Urans
[20] https://de.wikipedia.org/wiki/Kernkraftwerk#Wirkungsgrad

158ml: Volume of a Tyrannosaurus-Rex brain

The answer to this question can be found in this article:
http://www.icr.org/article/tyrannosaurus-rex-was-no-birdbrain/

78ml: spit produced by a human during the day in one hour

A person produces between 1 and 1.5 litres of spit per day[21], but spit production takes place mainly during the day[22]. If we calculate with 8 hours sleep per day and assume an average production of 1.25l, we arrive at 1.25/16ml = 78ml spit.

[21] https://www.thejpd.org/article/S0022-3913(01)54032-9/pdf
[22] https://www.smrv-journal.com/article/S1087-0792(01)90183-2/abstract