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1 Introduction

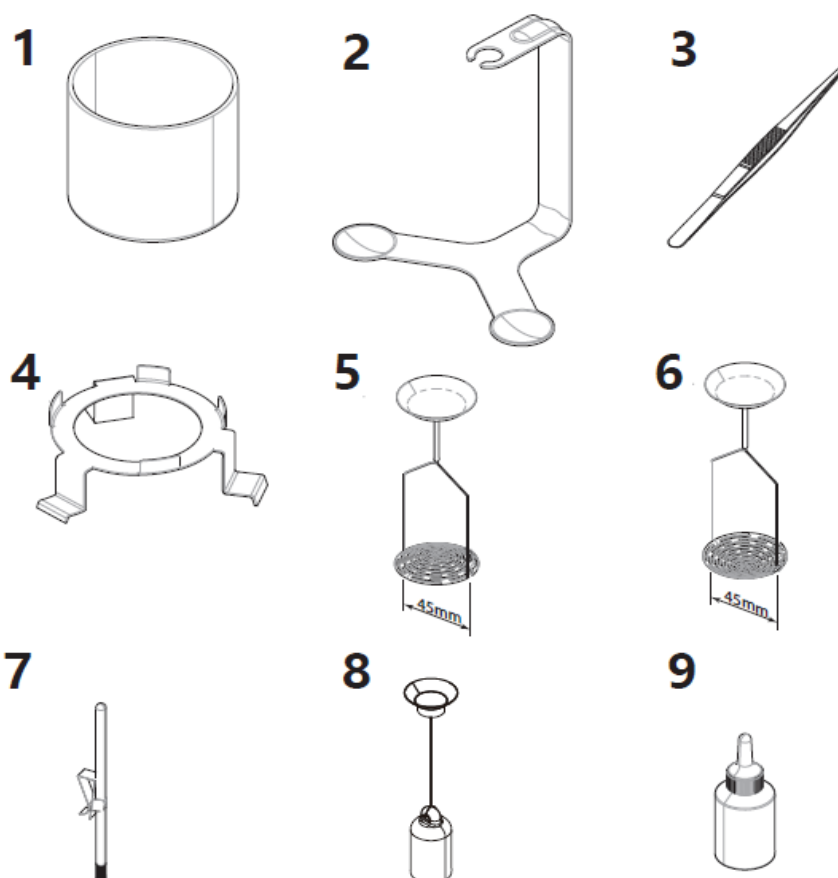
1.1 Before we begin

Thanks for purchasing the density determination kit for your OHAUS balances. With the aid of this kit you can use your balance for the determination of the density of solids and liquids. It is compatible with OHAUS Pioneer, Adventurer and Explorer models with readability of 1mg, 0.1mg and 0.01mg.

1.2 Standard equipment

The kit contains the individual parts shown in the illustration below.

For the density determination of liquids, you need the kit and also the optional 10ml sinker.



1 Glass beaker

3 Forceps

5 Holder for floating solids (45 mm)

7 Precision thermometer with holder

9 Wetting agent

2 Bracket

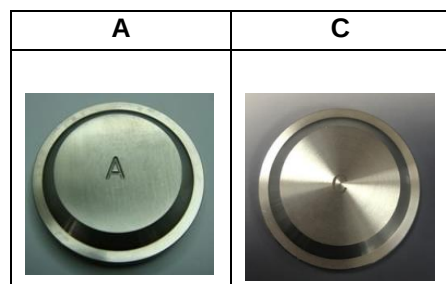
4 Platforms

6 Holder for non floating solids (45 mm)

8 Sinker 10ml

Note: choose different test components according to test samples.

- The holder for floating solids is suitable for solid samples with a density lower than the auxiliary liquid (such as distilled water);
- The holder for non floating solids is suitable for solid samples with a density greater than the auxiliary liquid (such as distilled water).
- Sinker is suitable for testing liquid samples.

Offsetting Weight**Pan Support**

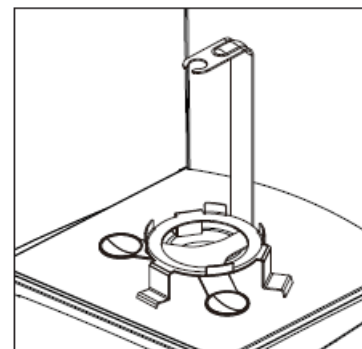
Readability Series	0.01mg	0.1mg		1mg	
	Pan Support	Pan Support	Offsetting Weight	Pan Support	Offsetting Weight
EX	F	D	/	E	A
AX	/	D	C	E	/
PX	F	D	C	E	/
PXP/PR/PJX	/	D	C	E	/

2 Preparing the balance for density

determinations This section describes how you can convert your balance to determine densities. Please follow the steps as below.

Select the pan support according to your balance as described in Section 1.2. Remove the cover of tape on the pan support, and adhere centrally to the bottom of the bracket (2).

1. Open the draft shield door and remove the weighing pan.
2. Place the bracket with the pan support on the weighing cone.
3. Place the platform (4) above the bracket. The three support feet should be between the weighing arms of bracket and stand stably on the bottom plate of draft shield.



NOTE: THE BRACKET MUST NOT TOUCH THE PLATFORM UNDER ANY CIRCUMSTANCES!

3 Principle of the density determination

The density ρ is the quotient of the mass m and the volume V .

$$\rho = \frac{m}{V}$$

The international system of units specifies **Kg/m³** as the unit of density. However, the unit **g/cm³** is better suited to lab purposes.

Density determinations are frequently performed by **Archimedes' principle**, which is also used with the density determination kit for the balances. This principle states that every solid body immersed in a fluid apparently loses weight by an amount equal to that of the fluid it displaces.

The procedure for the density determination by Archimedes' principle depends on whether the **density of solids or liquids to be tested** has to be determined.

4 Density determination of solids

4.1 Fundamentals

The density of a solid is determined with the aid of a liquid whose density ρ_0 is known (distilled water or ethanol are usually used as auxiliary liquids). The solid is weighed in air (A) and then in the auxiliary liquid (B). The density ρ can be calculated from the two weighings as follows:

$$\text{Density: } \rho = \frac{A}{A-B} (\rho_0 - \rho_L) + \rho_L$$

$$\text{Volume: } V = \alpha \frac{A-B}{\rho_0 - \rho_L}$$

ρ = Density of sample

A = Weight of sample in air

B = Weight of sample in the auxiliary liquid

ρ_0 = Density of the auxiliary liquid

ρ_L = Air density (0.0012 g/cm³)

α = Balance correction factor (0.99985), takes air buoyancy of the adjustment weight into account.

4.2 Performing the density determination of solids

Note: These instructions explain how to work with the density determination kit. They describe the procedure for performing a density determination manually.

If you need information about operating your balance, please refer to the instruction manual provided with the balance.

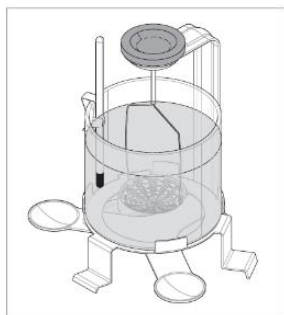


Figure 4.2-1

1. Prepare for the solid density test:

- Suspend the supplied thermometer from the edge of the beaker.
- Place the beaker on the platform and fill it with auxiliary liquid (liquid of known density, usually distilled water). Add enough liquid to ensure the solid is covered by at least 1 cm liquid after immersion.
- Add an appropriate amount of wetting agent (not more than 0.1% of the volume of auxiliary liquid).
- Suspend a suitable holder from the bracket to ensure that it does not touch the wall of the beaker or the thermometer*. If underload is displayed, use the offsetting weight as described in Chapter 1 (check figure 4.2-1 as an example).
- Close the draft shield doors, and wait for the wetting agent to completely dissolve and air bubbles disappear. If the sample can easily generate air bubbles in liquid (such as metals), place the sample in the holder and keep it immersed in liquid at the same time.
- After air bubbles are removed, open the draft shield doors, take out the sample and clean it. Ensure that there are no water droplets on the sample surface.
- According to the thermometer reading, input the auxiliary liquid temperature, close the draft shield doors and tare.

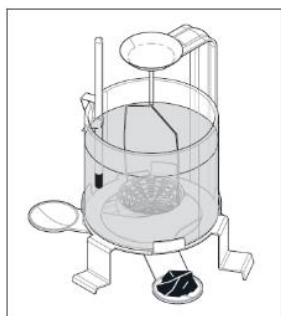


Figure 4.2-2-1

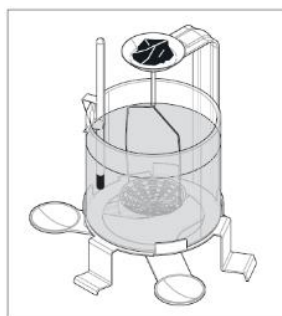


Figure 4.2-2-2

2. Measure the weight of the sample in the air.

- Open the draft shield doors and place the solid in one of the two weighing pans of the bracket. When solids with a weight greater than 20g are weighed in air, place it in the pan at the top of the holder. (See figure 4.2-2-2).
- Close the draft shield doors. Wait until the weight display of the balance is stable and record the displayed weight A.
- Open the draft shield doors, remove the solid from the pan, close the draft shield doors and tare the balance.

3. Measure the weight of the sample in the liquid.

- Open the draft shield doors, place the solid in the holder (see figure 4.2-3). Ensure that no air bubbles adhere to the solid (remove any air bubbles with a fine brush).
- Close the draft shield doors. Wait until the liquid level, the holder and the balance has reached stability, record the displayed weight B.

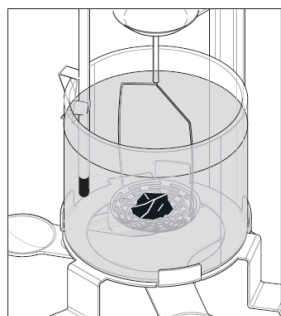


Figure 4.2-3

4. The balance automatically calculates and displays the density of the solid to be measured according to the internal density formula.

5. Take out the solid, wipe it clean and ensure that there are no water droplets on the surface of the sample and tweezers. Then repeat steps 2 and 3 at least 3 times. Average the results to determine the sample density.

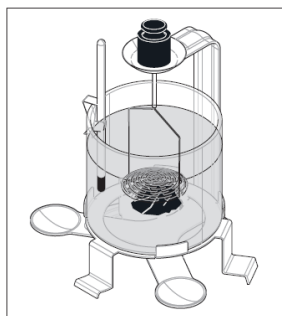


Figure 4.2-4

Note

*Holder Selection:

- If the density of the solid to be measured is greater than the density of the auxiliary liquid, use a holder for non-floating solids.
- If the density of the solid to be measured is less than the density of the auxiliary liquid, use a holder for floating solids (with additional weights if necessary). Immerse the solid to be measured completely under the auxiliary liquid surface, check figure 4.2-4.

4.3 Improving the accuracy of the result

The following tips should help you improve the accuracy of the results in the **density determination of solids**.

Temperature

Temperature has a great influence on the density of the auxiliary liquid. The effect of temperature on liquids can cause density changes of order of magnitude 0.1 to 1 ‰ per °C, which will directly affect the accuracy of the third decimal place of the density result. In order to obtain accurate density result, it is necessary to input the temperature of the auxiliary liquid into the balance before determining the density of the solid:

1. Use a thermometer to measure the temperature of the auxiliary liquid.
2. If the auxiliary liquid is ethanol, find the corresponding density value in Appendix 2 according to the measured temperature.

Surface tension of the auxiliary liquid

Adhesion of the auxiliary liquid to the suspension wires of the holder causes an apparent weight increase of up to 3mg.

As the holder is immersed in the auxiliary liquid in both weighings of the solid (in air and in the auxiliary liquid) and the balance is tared before every measurement, the influence of the apparent weight increase can be neglected.

In order to obtain accurate weighing results, an appropriate amount of wetting agent (not exceeding 0.1% of the auxiliary liquid volume) should be added dropwise to the auxiliary liquid before the solid density measurement.

Air Bubbles

Air bubbles may adhere to the immersed parts (solid, sinker, and holder) and influence the result owing to their buoyancy.

A bubble with a diameter of 1 mm causes a buoyancy of 0.5 mg, whereas one of diameter 2 mm results in buoyancy as high as 4 mg. To avoid air bubbles, we advise the following precautionary measures:

- a) Before density determination, use enclosed wetting agent (no more than 0.1% of the liquid). If the sample can easily generate air bubbles in liquid (such as metals), place the sample in the holder and keep it immersed in liquid at the same time.
- b) Remove grease traces from solvent-resistant solids.
- c) Clean holder at regular intervals.
- d) Never touched parts which are immersed with your hand.
- e) Gently shake holders on first-time immersion to dislodge any air bubbles.
- f) Remove tenaciously adhering air bubbles with a fine brush.

5 Density determination of liquids

5.1 Fundamentals

The density of a liquid is determined using a sinker of known volume. The sinker is weighed in air and then in the liquid whose density is to be determined. The density ρ can be determined from the two weighings as follows:

$$\rho = \alpha \frac{A-B}{V} + \rho_L$$

$$\rho = \alpha \frac{P}{V} + \rho_L$$

With an electronic balance it is possible to determine the weight of the displaced liquid P ($P=A-B$), and thus the buoyancy, allowing the preceding formula to be simplified to:

ρ = Density of liquid

A = Weight of sinker in air

B = Weight of sinker in the liquid

V = Volume of sinker

ρ_L = Air density (0.0012 g/cm^3)

α = Balance correction factor (0.99985), takes air buoyancy of the adjustment weight into account

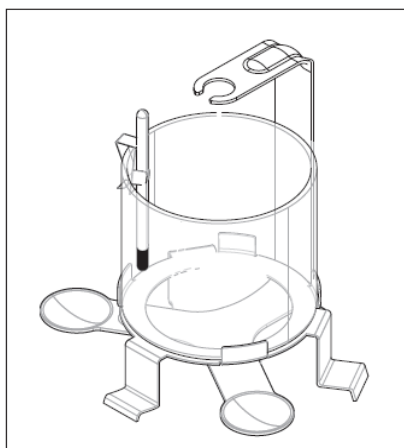
P = Weight of displaced liquid ($P = A - B$)

5.2 Performing the density determination of liquids

Note: These instructions explain how to work with the density determination kit. They describe the procedure for performing a density determination manually.

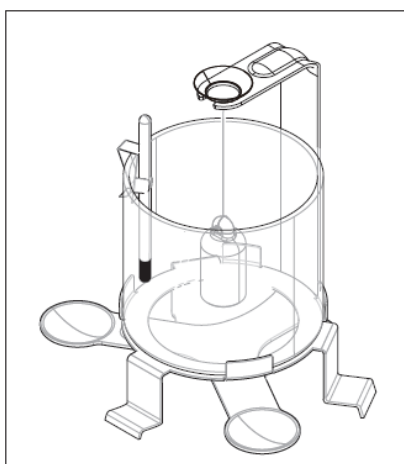
If you need information about operating your balance, please refer to the instruction manual which you received with the balance.

For the density determination of liquids, use the glass beaker (1) and the optional sinker (8).



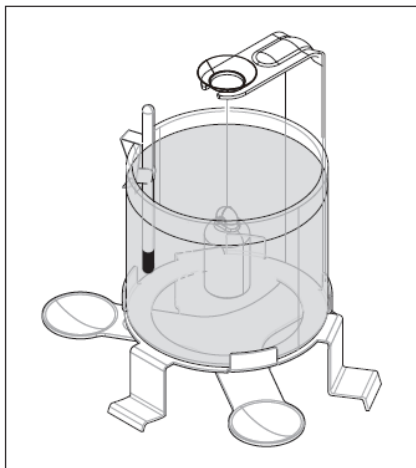
Prepare the balance for the density determination (install the platform and bracket) as described in Section 2.

Place the empty beaker (1) on the platform and suspend the thermometer supplied (7) from the edge of the beaker.



Suspend the sinker (8) from the bracket and ensure that it does not touch either the beaker or the thermometer.

Tare the balance.



Add the liquid whose density you wish to determine to the beaker (up to approx. 1 cm above the suspension eye of the sinker). Ensure that no air bubbles adhere to the sinker (remove any air bubbles with a fine brush).

Wait until the weight display of the balance is stable and note the displayed value P (weight of displaced liquid)

Now determine the density ρ of the liquid (at the temperature read off on the thermometer), according to the preceding formula (Section 5.1).

5.3 Improving the accuracy of the result

The following tips will help you improve the accuracy of the results in the **density determination of liquids**.

Volume tolerance of the sinker

The optional 10ml sinker recommended for the density determination of liquids corresponds to the requirements of the German Weights and Measures Regulation (EO 13-4, paragraph 9.21). The volume of the sinker including the upper half of the suspension wire is so adjusted that the maximum error in the density determination of water at a temperature of 20°C is $\pm 0.0005 \text{ g/cm}^3$

Air Bubbles

Air bubbles may adhere to the immersed parts (solid, sinker, and holder) and influence the result owing to their buoyancy.

A bubble with a diameter of 1 mm causes a buoyancy of 0.5 mg, whereas one of diameter 2 mm results in buoyancy as high as 4 mg. To avoid air bubbles, we advise the following precautionary measures:

- Before density determination, use enclosed wetting agent (no more than 0.1% of the liquid).
- Remove grease traces from solvent-resistant solids.
- Clean sinker at regular intervals.
- Gently shake the sinker on first-time immersion to dislodge any air bubbles.
- Remove tenaciously adhering air bubbles with a fine brush.

6 Supplementary information

This section offers information on the influencing factors which can have an adverse effect on the accuracy of the experimental results. In addition, you will find density tables for distilled water and ethanol in this section.

6.1 Precautions for density determination

1. Immersion depth of the holder or sinker

The sinker for the **density determination of liquids** is suspended from a platinum wire of **0.2 mm diameter**. In water the wire experiences a **buoyancy of approximately 0.3 mg per 10mm immersion depth**.

Example: If the liquid is 10mm above the suspension eye of the sinker, approx. 40mm wire is immersed. This results in a buoyancy of 1.2mg at densities around 1. Owing to division of the buoyancy by 10cm^3 (=volume of the sinker), the error in the result is negligibly small and need not be corrected.

The immiscible part of the holders for the **density determination of solids** comprises 2 wires **each of diameter 0.7mm**. With a liquid density of 1, this results in a **buoyancy of approx. 0.4mg millimeter immersion depth**.

In the weighing of the solid in air, the immersion depth of the holder remains the same. The buoyancy force on the holder is thus constant and can therefore be neglected. However, it is important to ensure that the **liquid level is not changed** between weighings (the change in the liquid level by immersion of the solid is usually insignificant).

2. Selection of samples

Not every sample is suitable for density measurement.

- When a porous material is immersed in a liquid, usually not all the air in the pores is displaced. This leads to buoyancy errors and thus the density of porous bodies can only be determined approximately.
- A highly viscous liquid will contaminate the sinker and affect the test results.

3. Test environment

The temperature has a great effect with liquids and causes density changes of order of magnitude 0.1 to 1% per °C. Therefore, during the density test, keep the temperature change at $\pm 0.5\text{ }^{\circ}\text{C}$.

4. Standards for density determination

Different samples have different density determination standards. It is recommended to refer to the requirements of international standards, prepare samples, and select the balance and the required weighing accuracy. For example, "ISO 1183-1 Plastics — Methods for Determining the Density of Non-Cellular Plastics" specifies that the density result is accurate to 0.001g/cm^3 ; while "ISO 3369 Impermeable Sintered Metal Materials and Hardmetals — Determination of Density" specifies that the density result is accurate to 0.01g/cm^3 .

6.2 Reference standard

ISO 1183-1	Plastics — Methods for Determining the Density of Non-Cellular Plastics
OIML G 14	Density Measurement Guidance for Inspectors
ASTM-D-792	Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics
ISO 3369	Impermeable Sintered Metal Materials and Hardmetals — Determination of Density
ISO 2781	Rubber, Vulcanized or Thermoplastic — Determination of Density

6.3 Spare Parts and Accessories

Part Number	Description
83034024	Sinker 10ml
30585297	Set of offsetting weights (composed of one A, one B and one C)
30596885	Set of holders (composed of one holder for floating solids and one holder for non-floating solids)

6.4 Density table for distilled water

T/°C	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
10.	0.99973	0.99972	0.99971	0.99970	0.99969	0.99968	0.99967	0.99966	0.99965	0.99964
11.	0.99963	0.99962	0.99961	0.99960	0.99959	0.99958	0.99957	0.99956	0.99955	0.99954
12.	0.99953	0.99951	0.99950	0.99949	0.99948	0.99947	0.99946	0.99944	0.99943	0.99942
13.	0.99941	0.99939	0.99938	0.99937	0.99935	0.99934	0.99933	0.99931	0.99930	0.99929
14.	0.99927	0.99926	0.99924	0.99923	0.99922	0.99920	0.99919	0.99917	0.99916	0.99914
15.	0.99913	0.99911	0.99910	0.99908	0.99907	0.99905	0.99904	0.99902	0.99900	0.99899
16.	0.99897	0.99896	0.99894	0.99892	0.99891	0.99889	0.99887	0.99885	0.99884	0.99882
17.	0.99880	0.99879	0.99877	0.99875	0.99873	0.99871	0.99870	0.99868	0.99866	0.99864
18.	0.99862	0.99860	0.99859	0.99857	0.99855	0.99853	0.99851	0.99849	0.99847	0.99845
19.	0.99843	0.99841	0.99839	0.99837	0.99835	0.99833	0.99831	0.99829	0.99827	0.99825
20.	0.99823	0.99821	0.99819	0.99817	0.99815	0.99813	0.99811	0.99808	0.99806	0.99804
21.	0.99802	0.99800	0.99798	0.99795	0.99793	0.99791	0.99789	0.99786	0.99784	0.99782
22.	0.99780	0.99777	0.99775	0.99773	0.99771	0.99768	0.99766	0.99764	0.99761	0.99759
23.	0.99756	0.99754	0.99752	0.99749	0.99747	0.99744	0.99742	0.99740	0.99737	0.99735
24.	0.99732	0.99730	0.99727	0.99725	0.99722	0.99720	0.99717	0.99715	0.99712	0.99710
25.	0.99707	0.99704	0.99702	0.99699	0.99697	0.99694	0.99691	0.99689	0.99686	0.99684
26.	0.99681	0.99678	0.99676	0.99673	0.99670	0.99668	0.99665	0.99662	0.99659	0.99657
27.	0.99654	0.99651	0.99648	0.99646	0.99643	0.99640	0.99637	0.99634	0.99632	0.99629
28.	0.99626	0.99623	0.99620	0.99617	0.99614	0.99612	0.99609	0.99606	0.99603	0.99600
29.	0.99597	0.99594	0.99591	0.99588	0.99585	0.99582	0.99579	0.99576	0.99573	0.99570
30.	0.99567	0.99564	0.99561	0.99558	0.99555	0.99552	0.99549	0.99546	0.99543	0.99540

6.5 Density table for ethanol

T/°C	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
10.	0.79784	0.79775	0.79767	0.79758	0.79750	0.79741	0.79733	0.79725	0.79716	0.79708
11.	0.79699	0.79691	0.79682	0.79674	0.79665	0.79657	0.79648	0.79640	0.79631	0.79623
12.	0.79614	0.79606	0.79598	0.79589	0.79581	0.79572	0.79564	0.79555	0.79547	0.79538
13.	0.79530	0.79521	0.79513	0.79504	0.79496	0.79487	0.79479	0.79470	0.79462	0.79453
14.	0.79445	0.79436	0.79428	0.79419	0.79411	0.79402	0.79394	0.79385	0.79377	0.79368
15.	0.79360	0.79352	0.79343	0.79335	0.79326	0.79318	0.79309	0.79301	0.79292	0.79284
16.	0.79275	0.79267	0.79258	0.79250	0.79241	0.79232	0.79224	0.79215	0.79207	0.79198
17.	0.79190	0.79181	0.79173	0.79164	0.79156	0.79147	0.79139	0.79130	0.79122	0.79113
18.	0.79105	0.79096	0.79088	0.79079	0.79071	0.79062	0.79054	0.79045	0.79037	0.79028
19.	0.79020	0.79011	0.79002	0.78994	0.78985	0.78977	0.78968	0.78960	0.78951	0.78943
20.	0.78934	0.78926	0.78917	0.78909	0.78900	0.78892	0.78883	0.78874	0.78866	0.78857
21.	0.78849	0.78840	0.78832	0.78823	0.78815	0.78806	0.78797	0.78789	0.78780	0.78772
22.	0.78763	0.78755	0.78746	0.78738	0.78729	0.78720	0.78712	0.78703	0.78695	0.78686
23.	0.78678	0.78669	0.78660	0.78652	0.78643	0.78635	0.78626	0.78618	0.78609	0.78600
24.	0.78592	0.78583	0.78575	0.78566	0.78558	0.78549	0.78540	0.78532	0.78523	0.78515
25.	0.78506	0.78497	0.78489	0.78480	0.78472	0.78463	0.78454	0.78446	0.78437	0.78429
26.	0.78420	0.78411	0.78403	0.78394	0.78386	0.78377	0.78368	0.78360	0.78351	0.78343
27.	0.78334	0.78325	0.78317	0.78308	0.78299	0.78291	0.78282	0.78274	0.78265	0.78256
28.	0.78248	0.78239	0.78230	0.78222	0.78213	0.78205	0.78196	0.78187	0.78179	0.78170
29.	0.78161	0.78153	0.78144	0.78136	0.78127	0.78118	0.78110	0.78101	0.78092	0.78084
30.	0.78075	0.78066	0.78058	0.78049	0.78040	0.78032	0.78023	0.78014	0.78006	0.77997

Density values of C_2H_5OH taken from "American Institute of Physics Handbook".