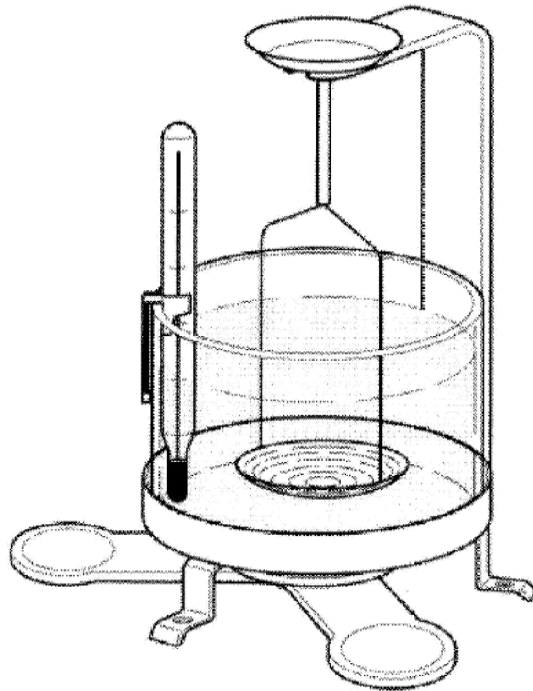




# Density Determination Kit Instruction Manual

## 天平密度测定组件 使用说明书



(适用于 EX/EP/VP/CAV/AV/AR/PA/CP 系列电子天平)

This Kit is compatible with OHAUS® Adventurer™, Adventurer™ Pro (except AV53x), Adventurer™ SL (except AS153x), Pioneer, Explorer® Pro, Voyager® and Voyager® Pro models with capacities up to 610g and readability of 0.1mg and 1mg, Explorer® models with capacities up to 1100g and readability of 0.1mg and 1mg. Before using this accessory, carefully read these instructions.



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# 1 Introduction

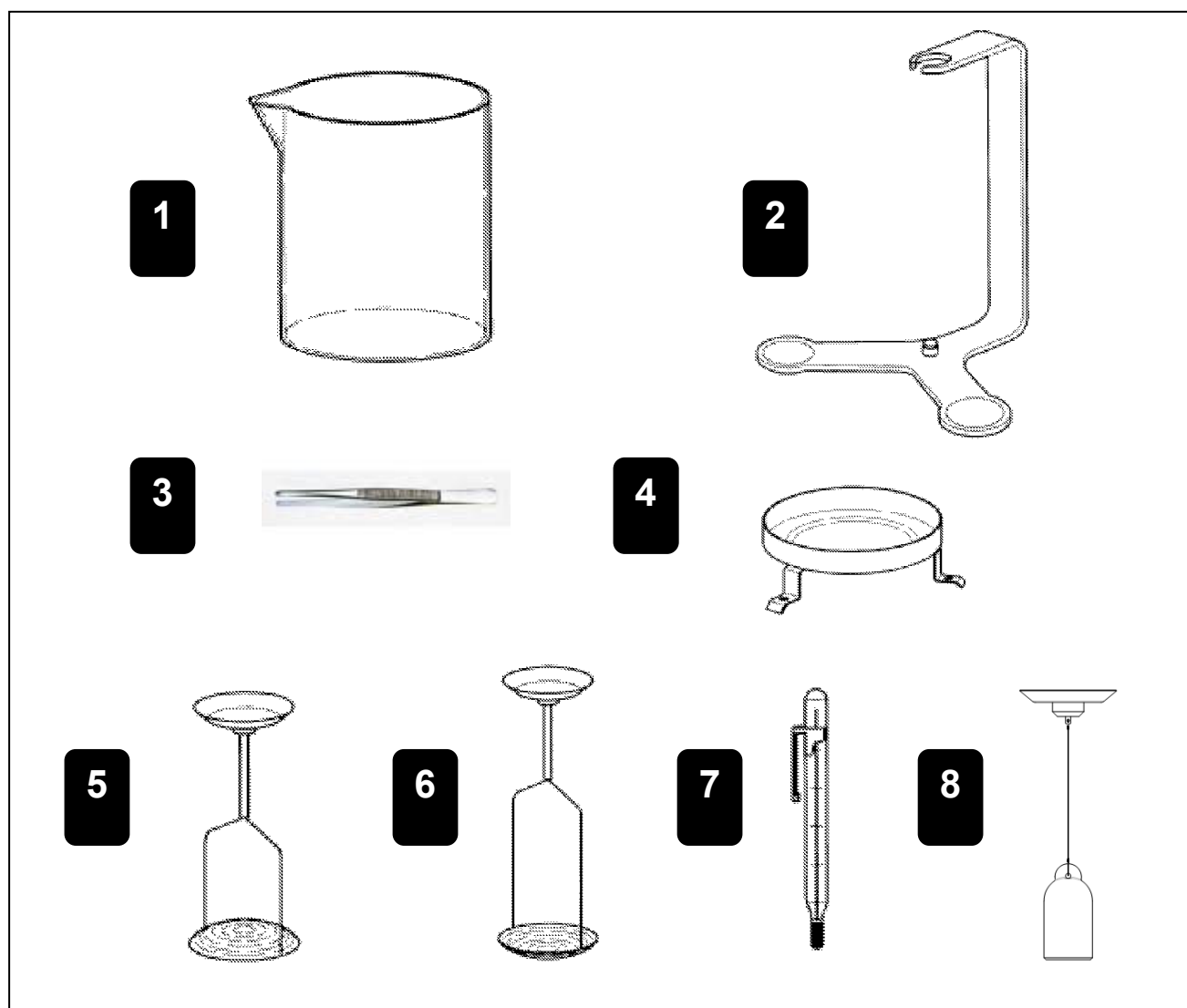
## 1.1 Before we begin

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.

## 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

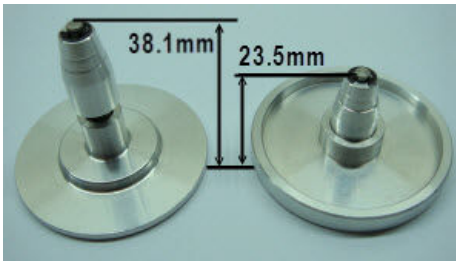
**7** Precision thermometer with holder

**2** Bracket

**4** Platforms

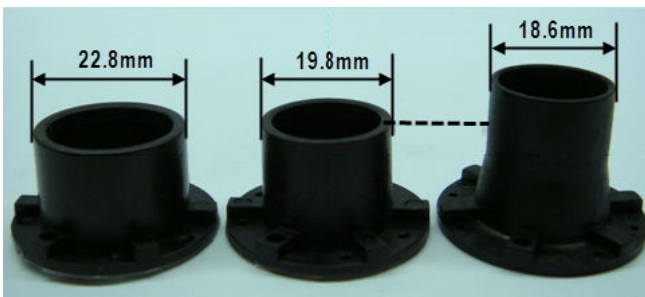
**6** Holder for non floating solids

**8** Sinker 10ml (optional equipment)



**9** Pan support (Height = 38.1mm)  
For AR 0.1mg/EP/VP

**10** Pan support (Height = 23.5mm)  
For PA 0.1mg/CP 0.1mg



**11** Pan support (Diameter = 22.8mm)  
For PA1mg/CP1mg/AR1mg/EX 1mg

**12** Pan support (Diameter = 19.8mm)  
For AV/CAV

**13** Pan support (Diameter = 18.6mm)  
For EX 0.1mg



**14** Off setting weights A

**15** Off setting weights B

Balances	Weights NO.	Quantity
EX 1mg	A	1
AV 1mg	A	1
EP/VP 1mg	A	3
PA/CP 1mg	B	1

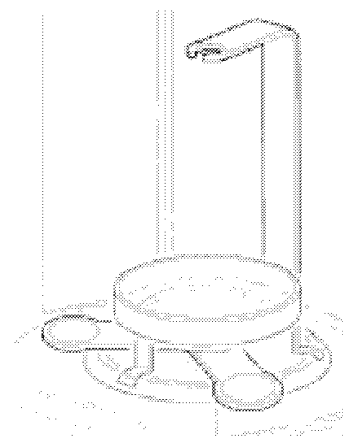
## 2 Preparing the balance for density determinations

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  $\rho$  is the quotient of the mass  $m$  and the volume  $V$ .

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

The international system of units specifies  $\text{Kg/m}^3$  as the unit of density. However, the unit  $\text{g/cm}^3$  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** 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  $\rho_0$  is known (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  $\rho$  can be calculated from the two weighings as follows:

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

$\rho$  = Density of sample

A = Weight of sample in air

B = Weight of sample in the auxiliary liquid

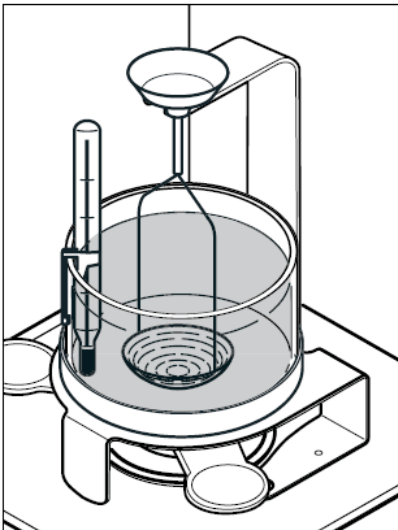
$\rho_0$  = Density of the auxiliary liquid

$\rho_L$  = Air density (0.0012 g/cm<sup>3</sup>)

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

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

### 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.

For the density determination of solids, use the glass beaker (2) and one of the two holders for solids which float (5) or sink (6). For certain OHAUS 1mg balances, use off setting weights according to your balance as described in Section 1.2.

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

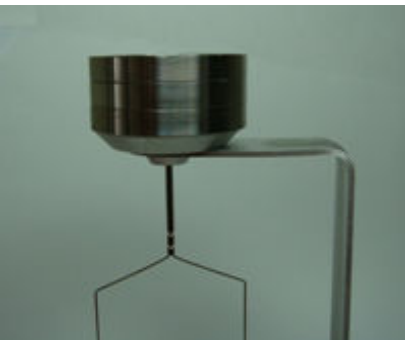
Suspend the supplied thermometer (7) from the edge of the beaker (1). Place the beaker on the platform and fill it with auxiliary liquid (liquid of known density  $\rho_0$ , usually distilled water or ethanol). Add enough liquid to ensure the solid is covered by at least 1 cm liquid after immersion.

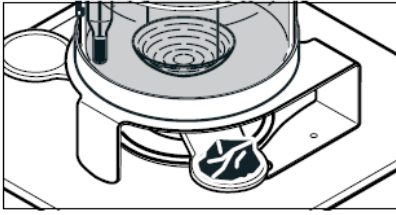
Suspend the suitable holder (5) or (6) for solids which float or sink from the bracket (the adjacent illustration shows the holder for solid which sink).

Ensure that no air bubbles adhere to the immersed part of the holder (Remove any air bubbles by moving the holder or by means of a fine brush).

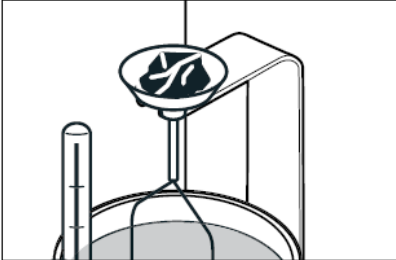
For certain OHAUS 1mg balances, place off setting weights on the holder (the adjacent illustration shows the weights for EP/VP 1mg balances).

Close the draft shield doors and tare the balance.





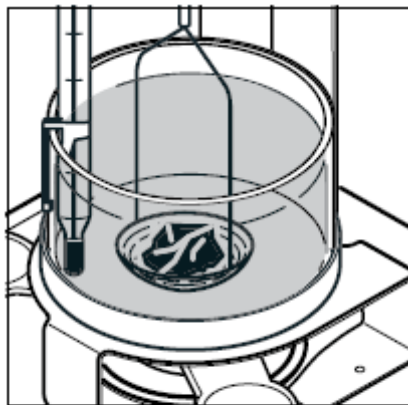
Place the solid in one of the two weighing pans of the bracket (2). Wait until the weight display of the balance is stable and note the displayed weight A (weight of sample in air).



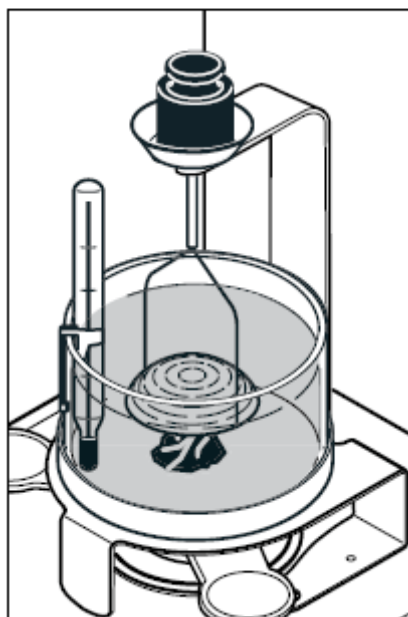
**Note for 0.1mg models**

When **solids with a weight greater than 20g** are weighed in air, place in the pan at the top of the holder (above 20g corner load errors may appear on one arm in the weighing).

Remove the solid from the pan, close the draft shield doors and tare the balance.



Place the solid after in the holder (6). Ensure that no air bubbles adhere to the solid (remove any air bubbles with a fine brush).



**Note**

With **solids with a density less than  $1\text{g/cm}^3$**  the holder for floating solids (5) must be used as it holds the solid body below the surface of the auxiliary liquid. If the buoyancy of the solid is greater than the weight of the holder, the holder must be weighted by placing an additional weight on the top weighing pan of the bracket. **After loading the additional weight, tare the balance and restart the density determination procedure by first weighing the solid in air (A) and then in the auxiliary liquid (B).**

Wait until the balance has reached stability and note the displayed weight B (weight of sample in the auxiliary liquid).

Now determine the density  $\rho$  of the solid according to the preceding formula (Section 4.1).



### 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

Solids are generally so insensitive to temperature fluctuations that the corresponding density changes are of no consequence. However, as work is performed with an auxiliary liquid in the density determination of solids following Archimedes' principle, their temperature must be taken into account as the temperature has a great effect with liquids and causes density changes of order of magnitude 0.1 to 1% per °C. This effect is already apparent in the third decimal place of the result.

**To obtain accurate results, we recommend that you always take the temperature of the auxiliary liquid into account in all density determinations.** You can take the appropriate values from a book of tables. You will find tables for distilled water and ethanol in Section 6.

#### 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.

If the greatest possible accuracy is required, use a few drops of the wetting agent.

## 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  $\rho$  can be determined from the two weighings as follows:

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

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:

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

$\rho$  = Density of liquid

$A$  = Weight of sinker in air

$B$  = Weight of sinker in the liquid

$V$  = Volume of sinker

$\rho_L$  = Air density (0.0012 g/cm<sup>3</sup>)

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

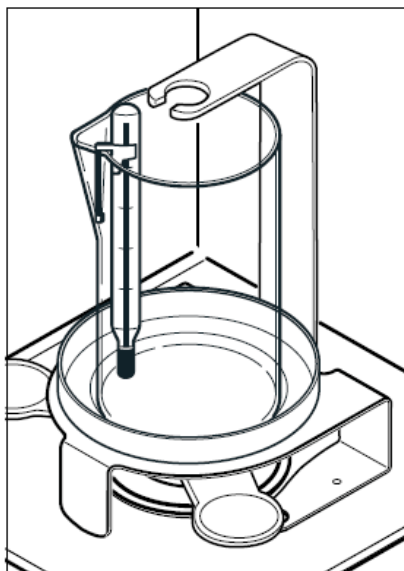
$P$  = Weight of displaced liquid ( $P = A - B$ )

## 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.

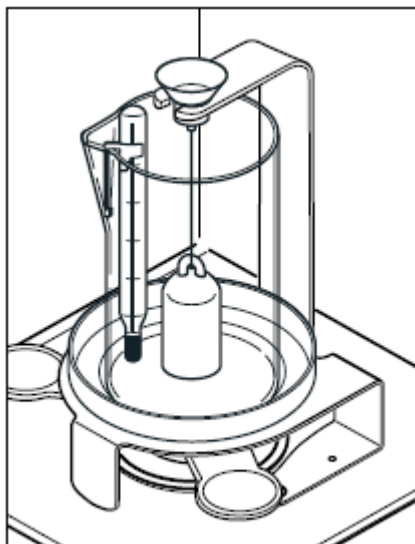
If you need information about operating your balance, please refer to the instruction manual which you received with the balance.

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



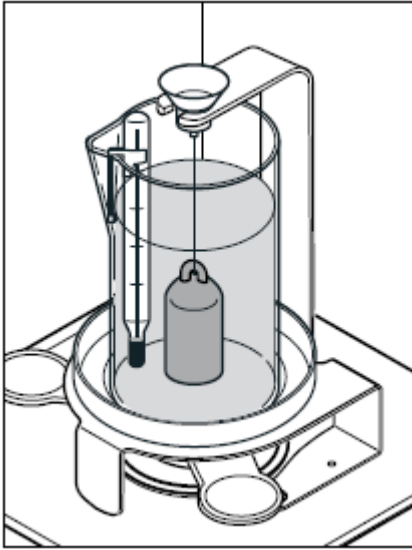
Prepare the balance for the density determination (install the platform and bracket) as described in Section 2.

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  $\rho$  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 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  $\pm 0.0005 \text{ g/cm}^3$

## 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 Influencing factors

In addition to temperature, air buoyancy and surface tension of the liquid, the following factors can affect the experimental results:

- Immersion depth of the holder or the sinker
- Air bubbles
- Porosity of the solid body

#### 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  $10\text{cm}^3$  (=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).

#### Air bubbles

With poorly wetting liquids (e.g. water without wetting agent), it is possible that air bubbles remain adhered 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:**

- Degrease solvent-resistant solids
- Clean holders and sinker at regular intervals, never touched parts which are immersed with your hand
- Gently shake holders and sinker on first-time immersion to dislodge any air bubbles.
- Remove tenaciously adhering air bubbles with a fine brush.
- Use enclosed or commercial wetting agent or organic liquids (the density change experienced by distilled water on the addition of wetting agent can be neglected).

**Porosity of the solid**

When solid bodies are 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.

**6.2 Density table for distilled water**

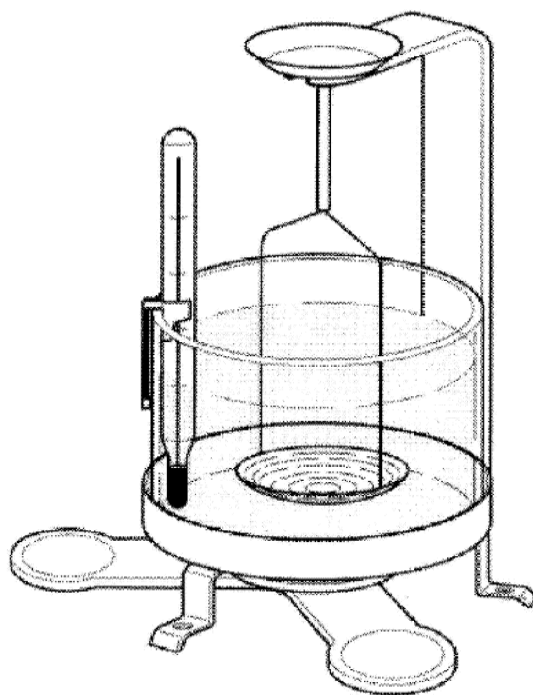
T/°C	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
10.	0.99973	0.99972	0.99971	0.99970	0.99969	0.99968	0.99967	0.99966	0.99965	0.99964
11.	0.99963	0.99962	0.99961	0.99960	0.99959	0.99958	0.99957	0.99956	0.99955	0.99954
12.	0.99953	0.99951	0.99950	0.99949	0.99948	0.99947	0.99946	0.99944	0.99943	0.99942
13.	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

### 6.3 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<sub>2</sub>H<sub>5</sub>OH taken from "American Institute of Physics Handbook".

# 奥豪斯天平密度测定组件 操作使用说明书

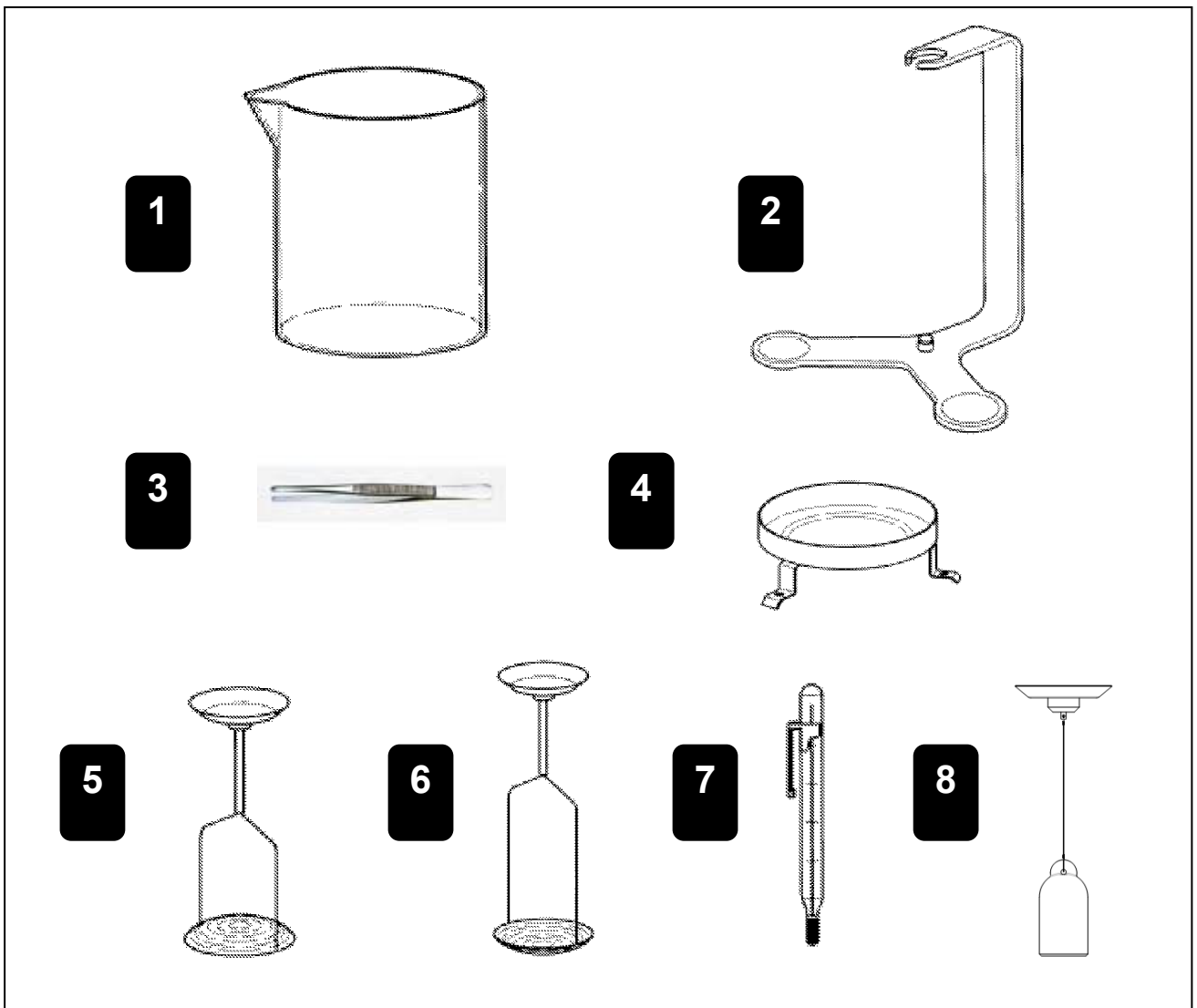


(适用于 EX/EP/VP/CAV/AV/AR/PA/CP 系列电子天平)

本组件适用于奥豪斯 Adventurer、Adventurer Pro (除 AV53x)、Adventurer SL (除 AS153x)、Pioneer、Explorer<sup>®</sup> Pro、Voyager<sup>®</sup> 和 Voyager<sup>®</sup> Pro 最大称量范围为 610g 以下、可读性为 0.1mg 和 1mg 的型号，Explorer<sup>®</sup> 最大称量范围为 1100g 以下、可读性为 0.1mg 和 1mg 的型号。

## 1 标准部件

小心地打开密度测定组件地包装，其中应包括下图所示的部件：



**1** 烧杯

**3** 镊子

**5** 漂浮固体挂篮

**7** 温度计

**2** 固定支架

**4** 容器支架

**6** 下沉固体挂篮

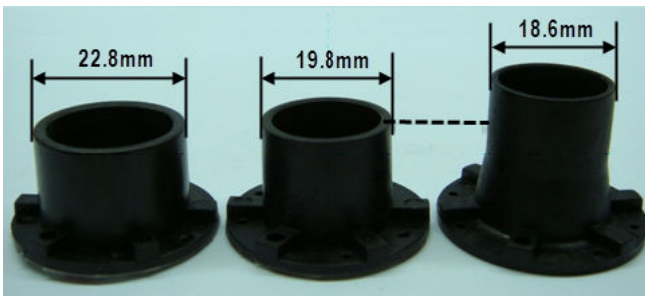
**8** 10ml 下沉锤（选配附件）





**9** 秤盘支架（高度 = 38.1mm）  
用于 AR 0.1mg/EP/VP

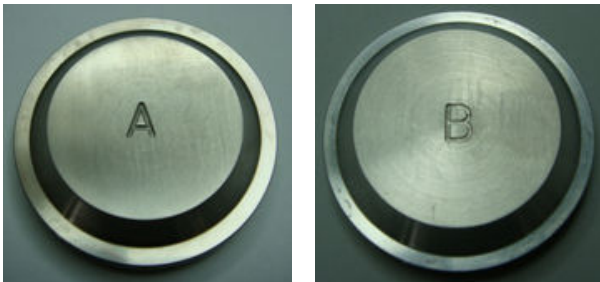
**10** 秤盘支架（高度 = 23.5mm）  
用于 PA 0.1mg/CP 0.1mg



**11** 秤盘支架（直径 = 22.8mm）  
用于 PA1mg/CP1mg/AR1mg/EX 1mg

**12** 秤盘支架（直径 = 19.8mm）  
用于 AV/CAV

**13** 秤盘支架（直径 = 18.6mm）  
用于 EX 0.1mg



**14** 配重块 A **15** 配重块 B

天平	配重块	数量
EX 1mg	A	1
AV 1mg	A	1
EP/VP 1mg	A	3
PA/CP 1mg	B	1

## 2 密度测定前天平的准备

该章节中将详细介绍使用天平测定固体和液体密度前的准备工作，详细步骤如下：

1. 根据天平选择相应的秤盘支架，将不干胶贴纸撕开，将秤盘支架贴在固定支架的底部正中央；
2. 推开天平边门移去秤盘及防风圈（0.1mg 天平配置）；
3. 把固定支架放到已经移去秤盘的中心位置，使其中心与天平的中线一致；
4. 把容器支架放置到固定支架上面，使其前支撑脚位于固定支架两个称量臂的中间，并确保容器支架不碰到固定支架；

## 3 密度测定的原理

物体的密度为其质量与体积的比值，具体公式如下：

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

物体密度测定通常是应用阿基米德原理来实现的。阿基米德定理规定：固体在液体中所受浮力的大小等于其排开液体的重量。对于未知固体或液体密度的测定具有不同的操作步骤。

### 3.1 固体密度测定

#### 3.1.1 测定公式

固体密度测定通常是使用一种已知密度液体（例如：水或乙醇）作为辅助液体，通过在空气（A）和辅助液体（B）中先后称量待测固体质量可计算求得其密度，具体公式如下：

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

$\rho$  = 待测固体密度

A = 待测固体密度在空气中的质量

B = 待测固体在辅助液体中质量

$\rho_0$  = 辅助液体密度

$\rho_L$  = 空气密度 (0.0012 g/cm<sup>3</sup>)

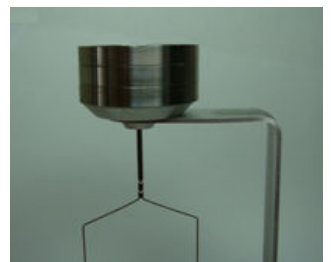
$\alpha$  = 空气浮力的校正因子 (0.99985)

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

#### 3.1.2 固体密度测定的操作步骤

按照章节 2 中步骤准备使用天平测定固体密度，具体操作步骤如下（见图 3.1）：

1. 悬挂温度计于烧杯壁上；
2. 放置烧杯到容器支架中心位置；
3. 将已知密度的参考液体（通常是水或乙醇）注入烧杯，确保待测固体能被液体完全浸没 1cm 以上；
4. 放置挂篮于固定支架上，确保其表面无气泡并不碰到烧杯或温度计；
5. 某些奥豪斯 1mg 天平需安装配重块。按照章节 1 所述，根据您所使用天平型号，如右图所示安装配重块（右图为 EP/VP 1mg 天平安装的 3 块配重块 A）；



6. 打开天平开关；
7. 关闭防风门并去皮重；
8. 打开天平防风门，如图所示将被测固体放置在固定支架的称量臂上或挂篮顶部的称盘中；若被测固体在空气中的质量大于 20g，请将其放置在挂篮顶部的称盘中进行称量（如右图）；
9. 关闭天平防风门，待天平稳定后记录称量结果 A；
10. 打开天平防风门，取下被测固体，关闭天平防风门并去皮重；
11. 打开天平防风门将固体放置在挂篮下部的称量网内，并确保无气泡附着在固体表面（可以用小刷子清除表面气泡）；
12. 关闭天平防风门，待天平稳定记录称量结果 B；
13. 根据密度公式计算待测固体密度。

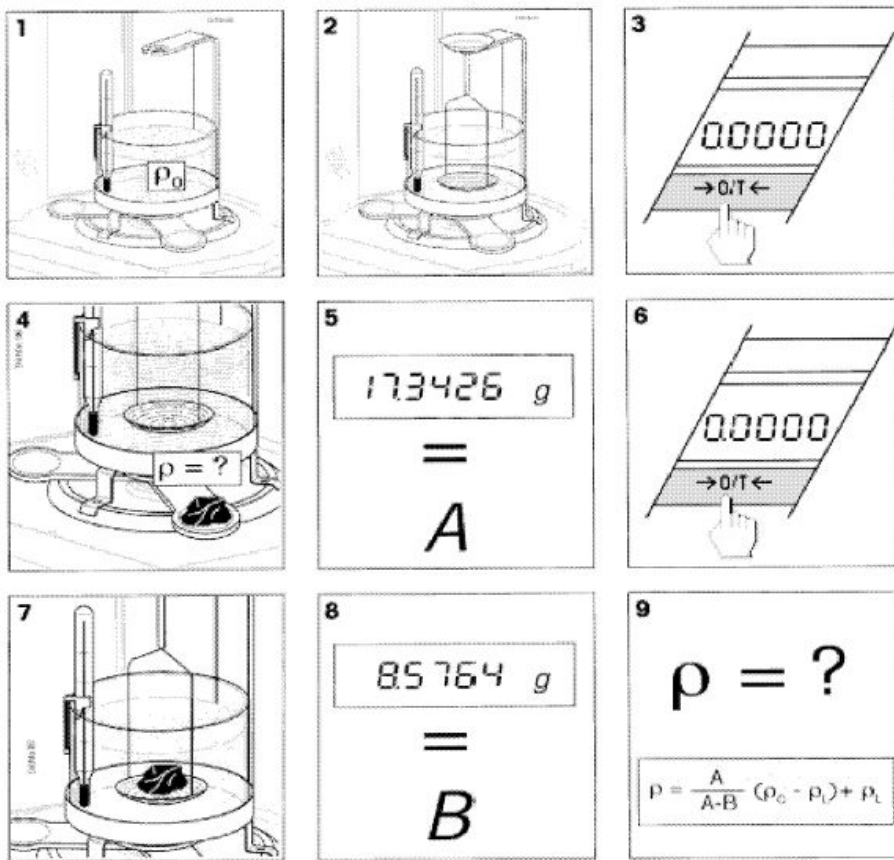
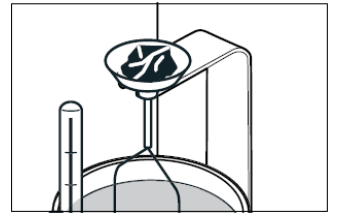
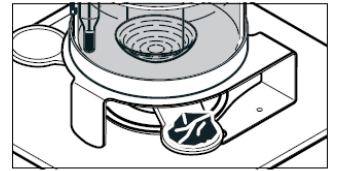
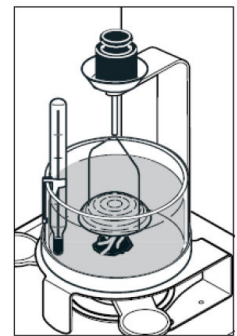


图 3.1 固体密度测定步骤

备注：对于较小密度固体的密度测定（ $\rho < \rho_0$ ），可以通过使用外加砝码和挂篮使其完全浸没在辅助液体液面以下来实现（详见右图）。在负载外加砝码之后，应当重新进行密度测定步骤即重新称量固体在空气中的质量 A，然后称量其浸没在辅助液体中的质量 B，通过公式计算求得未知固体密度  $\rho$ 。



### 3.1.3 提高测定固体密度结果的准确性

下面的提示可以帮助你提高测定固体密度结果的精确性。

#### 1. 温度影响

固体对温度的影响很不灵敏，对应的密度变化也无足轻重。根据“阿基米德”原理用辅助液体来进行固体密度测定，由于温度对液体密度有很大的影响（ $1\% \sim 0.1/^\circ\text{C}$ ），这会直接影响到称量结果小数点后第三位的准确性。

为了获得精确的称量结果，我们建议在固体密度测定中始终要考虑辅助液体的温度。附表 1 和附表 2 中给出了不

同温度下水和乙醇的密度表。

## 2. 辅助液体的表面张力影响

辅助液体对挂篮吊线的附着力会使得称量质量结果增加最大 3mg 左右。

由于在固体密度测定的过程中，吊篮始终浸没在辅助液体中，所以可以忽略辅助液体表面张力对称量结果的影响。

如果需要更为精确的称量结果，可以通过在辅助液体中滴加润湿剂来实现。

## 3.2 液体密度的测定

### 3.2.1 测定公式

未知液体的密度可以通过使用一个已知体积的下沉锤来实现。分别在空气中和待测密度液体中称量下沉锤的质量，计算可得液体密度，具体公式如下：

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

$\rho$  =待测液体密度

A =下沉锤在空气中质量

B =下沉锤在待测液体中质量

V =下沉锤得体积

$\rho_L$  =空气密度 (0.0012 g/cm<sup>3</sup>)

$\alpha$  =空气浮力的校正因子 (0.99985)

P =排开液体的质量 (P=A-B)

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

### 3.2.2 液体密度测定的操作步骤

按照章节 2 中步骤准备使用天平测定液体密度，具体操作步骤如下（详见图 3.2）：

1. 悬挂温度计于烧杯壁上；
2. 放置烧杯到容器支架中心位置；
3. 悬挂下沉锤（选件）于固定支架上，并确保其不碰到烧杯或温度计；
4. 打开天平开关；
5. 关闭防风门并去皮重
6. 打开防风门注入被测液体使下沉锤挂钩完全浸没 1cm 以上，确保下沉锤周围没有气泡（可以用小刷子清除表面气泡）；
7. 关闭天平防风门，等待天平稳定后记下读数 P；
8. 根据密度公式计算待测液体密度。

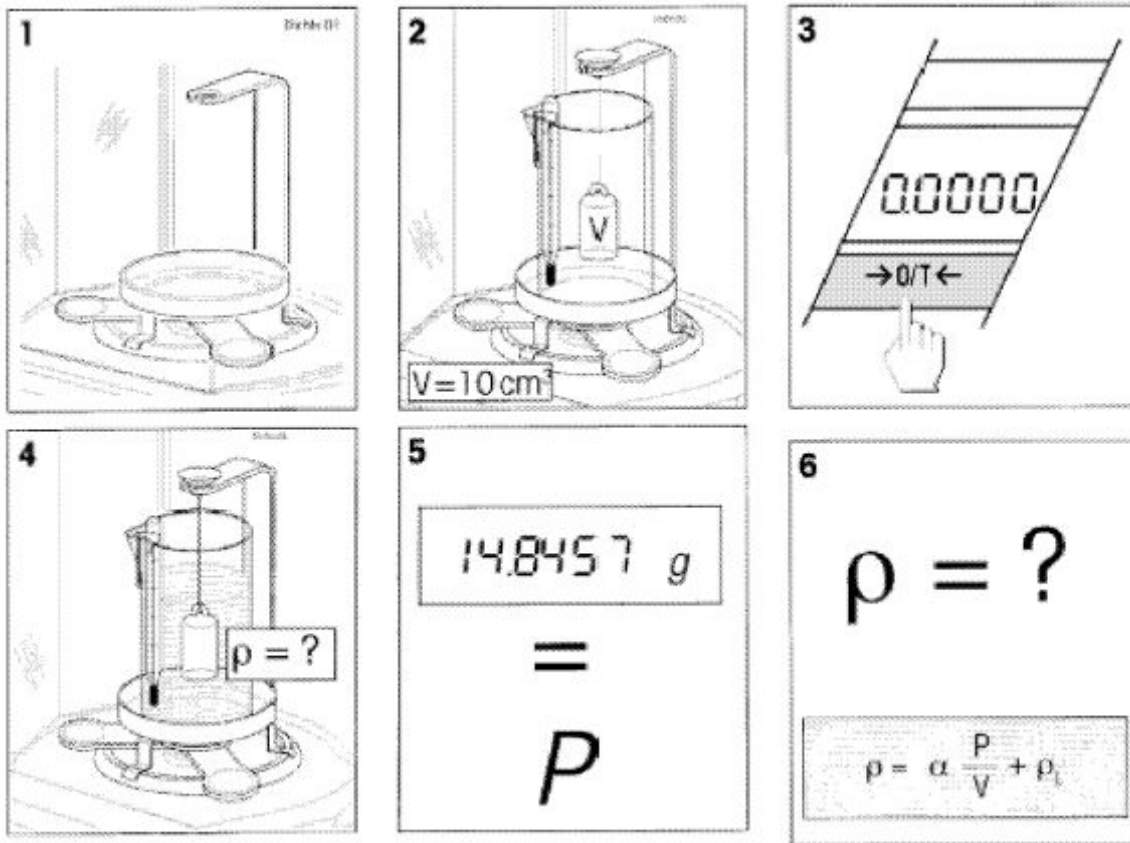


图 3.2 液体密度测定步骤

### 1.2.3 提高测定液体密度结果的准确性

下沉锤的体积 在液体密度测定中使用的下沉锤符合德国砝码和称量规程 (the German Weights and Measures Regulation E013-4, paragraph 9.21)。应当对选件下沉锤体积包括悬挂金属丝上半部进行校准使得在 20°C 时测定蒸馏水密度的误差小于为  $\pm 5\% \text{g/cm}^3$ 。

## 4 附录

### 4.1 密度测定的影响因素

除了在上一章节中谈到的辅助液体温度及其表面张力，下沉锤的体积，以下因素也可能影响天平对物体密度的测定结果。

#### 1. 挂篮和下沉锤在液体中浸没深度：

在测定液体密度中所用到的下沉锤是使用直径为 0.2mm 的铂丝悬挂在待测液体中。该金属丝在密度为  $1\text{g/cm}^3$  去离子水中受到的浮力约为 0.3mg/10mm 浸没深度。例如：如果下沉锤挂钩浸没在密度为  $1\text{g/cm}^3$  去离子水中 10mm 以下，大约有 40mm 的铂丝被浸没，这使得铂丝在去离子水受到得浮力约为 1.2mg，与 10ml 下沉锤受到得浮力相比可以忽略不计。

在测定固体密度中所用到得挂篮是使用两根直径为 0.7mm 的铂丝悬挂在待测液体中，其在密度约为  $1\text{g/cm}^3$  去离子水中受到的浮力约为 0.4mg/mm 浸没深度。当在空气中和液体中称量固体质量时，挂篮在液体中的浸没深度是基本不变的（忽略由于固体浸没引起液面的变化），所以挂篮受到的浮力是恒定的可以忽略不计。如果固体浸没引起液面的显著变化，我们应当考虑挂篮在液体中的浸没深度对测定密度结果的影响。

#### 2. 气泡：

对于润湿性较差的液体（没有添加任何润湿剂），气泡可能会附着在浸没的部件上如待测固体、下沉锤或挂篮，从而影响称量结果（气泡浮力）。直径 1mm 气泡产生的浮力约为 0.5mg，而直径 2mm 气泡产生的浮力却高达 4mg，所以为了避免空气气泡，我们建议采用以下预防手段：

- 去除固体表面抗溶剂的污质
- 定期清洁挂篮和下沉锤

- c) 在密度测定过程中避免用手接触浸没在液体中的部件
- d) 在第一次使用时轻轻抖动挂篮和下沉锤以去除表面气泡
- e) 用细毛刷清除粘着气泡
- f) 使用润湿剂或其他有机液体（忽略滴加润湿剂对液体密度的影响）

### 3. 固体的多孔型；

当固体浸没在液体中时，并不是孔中所有的气体均被液体替代，这就会引起浮力的误差，所以多孔性固体物质的密度只能被粗略得测定。

## 4.2 附表 1 蒸馏水密度表

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

## 4.3 附表 2 乙醇密度表

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

C<sub>2</sub>H<sub>5</sub>OH 密度值摘自“美国学院物理手册”



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