



First stage

Chapter 5: Density, Specific Gravity, and Specific Volume

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Objectives

- ✓ Define density, specific gravity, and specific volume and determine each through appropriate calculations.
 - ✓ Apply specific gravity correctly in converting weight to volume and volume to weight.
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Density (*d*) is **mass per unit volume** of a substance.

Unit: *grams per cubic centimeter (g/cc)*

For water: 1 *gram* is defined as the mass of 1 cc of water at 4C,

→ density of water is **1 g/cc**

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

Thus, if 10 mL of sulfuric acid weighs 18 g, its density is:

$$\text{Density} = \frac{18 \text{ (g)}}{10 \text{ (mL)}} = 1.8 \text{ grams per milliliter}$$

Specific gravity (*sp gr*) is a ratio, *expressed decimally*, of the weight of a substance to the weight of an equal volume of a substance chosen as a standard, both substances at the same temperature or the temperature of each being known.

$$\text{Specific gravity} = \frac{\text{Weight of substance}}{\text{Weight of equal volume of water}}$$

- ✓ In the *United States Pharmacopeia*, the standard temperature for specific gravities is 25°C, except for that of alcohol, which is 15.56°C.
- ✓ Water is used as the standard for the specific gravities of liquids and solids
- ✓ The most useful standard for gases is hydrogen.

EX: If 10 mL of sulfuric acid weighs 18 g, and 10 mL of water, under similar conditions, weighs 10 g, the specific gravity of the acid is

$$\text{Specific gravity} = \frac{\text{Weight of substance}}{\text{Weight of equal volume of water}} = \frac{18 \text{ (g)}}{10 \text{ (g)}} = 1.8$$

Substances with sp. gr. < 1 are lighter than water.

Substances with sp. gr. > 1 are heavier than water

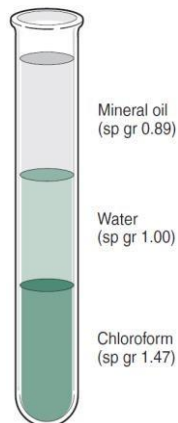


TABLE 5.1 SOME REPRESENTATIVE SPECIFIC GRAVITIES AT 25°C

AGENT	SP GR
Ether (at 20°C)	0.71
Isopropyl alcohol	0.78
Acetone	0.79
Alcohol	0.81
Liquid petrolatum	0.87
Peppermint oil	0.90
Olive oil	0.91
Peanut oil	0.92
Cod liver oil	0.92
Castor oil	0.96
Water	1.00
Propylene glycol	1.03
Clove oil	1.04
Liquefied phenol	1.07
Polysorbate 80	1.08
Polyethylene glycol 400	1.13
Glycerin	1.25
Syrup	1.31
Hydrochloric acid	1.37
Nitric acid	1.42
Chloroform	1.47
Nitroglycerin	1.59
Phosphoric acid	1.70
Mercury	13.6

Density vs Specific Gravity

Density	Specific gravity
Density has a unit.	Dimensionless (has no unit, it is a ratio)
Value changes depending on the unit	value is constant under controlled conditions
Water density = 1g/ml = 1000g/L = 62.5 lb/ft ³	Specific gravity of water always =1

Calculations of specific gravity

1. known weight and volume

$$\text{Specific gravity} = \frac{\text{Weight of substance}}{\text{Weight of equal volume of water}}$$

Ex: If 54.96 mL of an oil weighs 52.78 g, what is the specific gravity of the oil?

weight of equal volume of water: 54.96 mL of water weighs 54.96 g

$$\text{Specific gravity of oil} = \frac{52.78 \text{ g}}{54.96 \text{ g}} = 0.9603$$

EX: If a pint of a certain liquid weighs 601 g, what is the specific gravity of the liquid?

Equal volume of water = 1 pint = 16 fl. oz.

16 fl. oz. of water weighs 473 g

$$\text{Specific gravity} = \frac{\text{Weight of substance}}{\text{Weight of equal volume of water}}$$

$$\text{Specific gravity of liquid} = \frac{601 \text{ g}}{473 \text{ g}} = 1.27$$

TABLE 2.3 SOME USEFUL EQUIVALENTS

Equivalents of Length		
1 inch	=	2.54 cm
1 meter (m)	=	39.37 in
Equivalents of Volume		
1 fluidounce (fl. oz.)	=	29.57 mL
1 pint (16 fl. oz.)	=	473 mL
1 quart (32 fl. oz.)	=	946 mL
1 gallon, US (128 fl. oz.)	=	3785 mL
1 gallon, UK	=	4545 mL
Equivalents of Weight		
1 pound (lb, Avoirdupois)	=	454 g
1 kilogram (kg)	=	2.2 lb

2. Pycnometer or specific gravity bottle



FIGURE 5.2 Examples of pycnometers used to determine the specific gravity of liquids. Shown are 1-mL and 25-mL sizes. See text for description of their use. (Courtesy of Thomas Scientific.)

$$\text{Specific gravity} = \frac{\text{Weight of substance}}{\text{Weight of equal volume of water}}$$

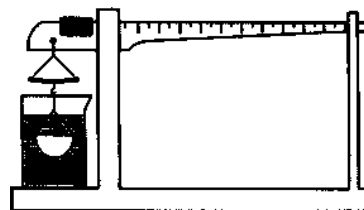
Determine the weight of the pycnometer empty, filled with water, and filled with liquid for which we need to determine the specific gravity. Use the measurements in the equation below

3. Displacement or plummet method

Based on Archimedes' principle: A body immersed in a liquid displaces an amount of the liquid equal to its own volume and suffers an apparent loss in weight equal to the weight of the displaced liquid.

Weigh the plummet in air, suspended in water, and suspended in the liquid for which specific gravity is to be determined. From these weights we can determine the weights of equal volumes needed in the calculations

$$\text{Specific gravity} = \frac{\text{Weight of substance}}{\text{Weight of equal volume of water}}$$



Use of specific gravity in calculation of weight and volume

- When specific gravity is used as a factor in a calculation, the result should contain no more significant figures than the number in the factor.
- Specific gravity is a factor that expresses how much *heavier or lighter* a substance is than water where water is the standard with a sp gr of 1.0.
- A liquid with a specific gravity of 1.25 is 1.25 times as heavy as water
- A liquid with a specific gravity of 0.85 is 0.85 times as heavy as water.

Calculating weight, knowing the volume and Sp Gr

$$\text{Grams} = \text{Milliliters} \times \text{Specific gravity}$$

$$\text{Weight} = \text{volume} \times \text{Sp Gr}$$

Ex: What is the weight, in grams, of 2 fl. oz. of a liquid having a specific gravity of 1.118?

convert fl.oz to ml: $2 \times 29.57 \text{ mL} = 59.14 \text{ mL}$

59.14 mL of water weigh 59.14 g

$59.14 \text{ g} \times 1.118 = 66.12 \text{ g}$

calculating volume, knowing the weight and Sp Gr

Milliliters = Grams / Specific gravity

volume = weight / Sp Gr

What is the volume, in milliliters, of 492 g of nitric acid with a specific gravity of 1.40?

492 g of water measure 492 mL

$492 \text{ mL} / 1.40 = 351 \text{ mL}$

What is the volume, in milliliters, of 1 lb of methyl salicylate with a specific gravity of 1.185?

1 lb = 454 g

454 g of water measure 454 mL

$454 \text{ mL} / 1.185 = 383.1 \text{ mL}$

What is the volume, in pints, of 50 lb of glycerin having a specific gravity of 1.25?

50 lb = 454 g $\times 50 = 22,700 \text{ g}$

22,700 g of water measure 22,700 mL and 1 pint = 473 mL

$$22,700 \text{ mL} / 1.25 = 18,160 \text{ mL}$$

$$18,160 \text{ mL} / 473 \text{ mL per pint} = 38.4 \text{ pints}$$

What is the cost of 1000 mL of glycerin, specific gravity 1.25, bought at \$54.25 per pound?

1000 mL of water weigh 1000 g

$$\text{Weight of 1000 mL of glycerin} = 1000 \text{ g} \times 1.25 = 1250 \text{ g}$$

$$1 \text{ lb} = 454 \text{ g}$$

$$454 \text{ (g)} \quad (\$) 54.25$$

$$1250 \text{ (g)} \quad ?$$

$$? = ((\$) 54.25 \times 1250 \text{ g}) / 454 \text{ g} = \$149.37$$

Special Considerations of Specific Gravity

- **Pharmaceutical Applications**
- Conversion of the weight of an ingredient to volume and vice versa
 - Measure the weight when formula is expressed in unit of volume or weigh an equivalent amount when formula is expressed in units of volume
 - Calculate equivalent strength of a preparation on the basis of weight or volume
- Automated Total Parenteral Nutrition (TPN) compounders
- **Clinical applications**
- Important factor in urinalysis
- Normal Sp Gr of urine is 1.010 – 1.025
- Higher than normal sp gr: urine is concentrated possible due to excess electrolytes, glucose, protein or water loss.

- Lower than normal sp gr: urine is dilute possibly due to renal disease or diabetes insipidus

Specific Volume

Specific volume, in pharmaceutical practice, is an abstract number representing the ratio, expressed decimally, of the volume of a substance to the volume of an equal weight of another substance taken as a standard, both having the same temperature.

Water is the standard

Specific gravity: comparison of weights of equal volumes

Specific volume: comparison of volumes of equal weights

➤ Specific volume = $1/\text{specific gravity}$

If the substance is heavier than water: sp gr >1 , specific volume < 1

If the substance is lighter than water: sp gr < 1, specific volume >1

Specific gravity: comparison of weights of equal volumes

Specific volume: comparison of volumes of equal weights

➤ Specific volume = $1/\text{specific gravity}$

Ex: Calculate the specific volume of a syrup, 91.0 mL of which weighs 107.16 g.

Specific volume of the syrup = $(91 \text{ ml})/(107.16 \text{ ml}) = 0.849$

The specific gravity of the syrup = $1/0.849 = 1.178$

CASE IN POINT 5.1¹

Rx Lactic Acid

Salicylic Acid aa. 1.5 g

Flexible Collodion qs ad 15 mL

Sig: Apply one drop to wart twice a day.

Label: Wart remover. For external use only.

Lactic acid is available as a liquid containing 85 g of the acid in 100 g of solution (sp.gr. 1.21). Calculate the quantity of this solution, in milliliters, needed to fill the prescription.

Lactic acid concentration 85 g/100 g of solution

We need 1.5 g to fill the prescription, now convert the weight to volume

85 g 100 g

1.5 g ? ? = (1.5 g X 100 g)/85 g = 1.765 g

Now calculate the volume of 1.765 g of lactic acid using its sp gr

ml = g / sp gr = 1.765 / 1.21 = 1.459 = 1.46 ml

HW:

Problem 11

Problem 27

Problem 32

Problem 33

PRACTICE PROBLEMS

Calculations of Density

1. If 250 mL of alcohol weighs 203 g, what is its density?
2. A piece of copper metal weighs 53.6 g, and has a volume of 6 mL. Calculate its density.

Calculations of Specific Gravity

3. If 150 mL of a sorbitol solution weigh 170 g, what is its specific gravity?
4. If a liter of a cough syrup weighs 1285 g, what is its specific gravity?
5. If 500 mL of ferric chloride solution weighs 650 g, what is its specific gravity?
6. If 380 g of cottonseed oil measures 415 mL, what is its specific gravity?
7. If 2 fl. oz. of glycerol weighs 74.1 g, what is its specific gravity?
8. Five pints of diluted hydrochloric acid weighs 2.79 kg. Calculate its specific gravity.
9. A pycnometer weighs 21.62 g. Filled with water, it weighs 46.71 g; filled with another liquid, it weighs 43.28 g. Calculate the specific gravity of the liquid.

10. A glass plummet weighs 14.35 g in air, 11.40 g when immersed in water, and 8.95 g when immersed in sulfuric acid. Calculate the specific gravity of the acid.

11. A modified Ringer's Irrigation has the following formula:

Sodium chloride	8.6	g
Potassium chloride	0.3	g
Calcium chloride	0.33	g
PEG 3350	60	g
Water for injection	ad	1000 mL

Assuming that 980 mL of water is used in preparing the irrigation, calculate its specific gravity.

Calculations of Specific Volume

12. If 73.42 g of a liquid measures 81.5 mL, what is its specific volume?
13. If 120 g of acetone measures 150 mL, what is its specific volume?
14. The specific gravity of alcohol is 0.815. What is its specific volume?
15. If chloroform has a specific gravity of 1.476, what is its specific volume?

Calculations of Weight or Volume Using Specific Gravity

Note: Use the information in Table 5.1 if necessary.

16. Calculate the weight, in grams, of 100 mL of each of the following:
 - (a) acetone
 - (b) liquid petrolatum
 - (c) syrup
 - (d) nitroglycerin
 - (e) mercury
17. What is the weight, in kilograms, of 5 liters of sulfuric acid with a specific gravity of 1.84?
18. What is the weight, in pounds, of 5 pints of nitric acid?
19. What is the weight, in kilograms, of 1 gallon of sorbitol solution having a specific gravity of 1.285?
20. If 500 mL of mineral oil is used to prepare a liter of mineral oil emulsion, how many grams of the oil, having a specific gravity of 0.87, would be used in the preparation of 1 gallon of the emulsion?
21. Calculate the volume, in milliliters, of 100 g of each of the following:
 - (a) peanut oil
 - (b) castor oil
 - (c) polysorbate 80
 - (d) phosphoric acid
 - (e) mercury
22. What is the volume, in milliliters, of 1 lb of benzyl benzoate having a specific gravity of 1.120?
23. What is the volume, in milliliters, of 1 kg of sulfuric acid with a specific gravity of 1.83?
24. Calculate the corresponding weights of liquefied phenol and propylene glycol needed to prepare 24 15-mL bottles of the following formula for a cold sore topical liquid:

Liquefied phenol	0.4 mL
Camphor	0.5 g

Benzocaine	2.2 g
Ethanol	65 mL
Propylene glycol	17 mL
Purified water ad	100 mL

25. Calculate the total weight of the following formula for a pediatric chewable gummy gel base for medication.⁷

Gelatin	43.4 g
Glycerin	155 mL
Purified Water	21.6 mL

26. Calculate the number of milliliters of polysorbate 80 required to prepare 48 100-g tubes of the following formula for a progesterone vaginal cream.⁸

Progesterone, micronized	3 g
Polysorbate 80	1 g
Methylcellulose 2% Gel	96 g

27. If fifty glycerin suppositories are made from the following formula, how many milliliters of glycerin, having a specific gravity of 1.25, would be used in the preparation of 96 suppositories?

Glycerin	91 g
Sodium stearate	9 g
Purified water	5 g

28. Two 10-mL samples of urine have specific gravities of 1.003 and 1.030. What is the difference in weight, in milligrams, between the two samples?

29. How many grams of dextrose are contained in a 250-mL intravenous infusion of a dextrose injection containing 60 g of dextrose per 100 mL if its specific gravity is 1.20?

30. $\mathcal{R}^9$

Testosterone propionate	2 g
Mineral Oil, light	10 g
Polysorbate 80	1 g
Methylcellulose 2% gel	87 g

The specific gravity of light mineral oil is 0.85 and that of polysorbate 80 is 1.08. Calculate the milliliters of each needed to fill the prescription.

31. Cocoa butter (theobroma oil), which is solid at room temperature and melts at 34°C, has a specific gravity of 0.86. If a formula calls for 48 mL of theobroma oil, what would be the corresponding weight of cocoa butter to use?
32. A transdermal patch for smoking cessation contains 30 mg of liquid nicotine per patch. If nicotine has a specific gravity of 1.01, how many milliliters of the agent are required to manufacture 1 million patches?

Calculations of Drug Costs Using Specific Gravity

33. The formula for 1000 g of polyethylene glycol ointment calls for 600 g polyethylene glycol 400. At \$19.15 per pint, what is the cost of the polyethylene glycol 400, specific gravity 1.140, needed to prepare 4000 g of the ointment?
34. Glycerin, USP (specific gravity 1.25) costs \$54.25 per pound. If students in a dispensing laboratory use 1 pint of glycerin in preparing compounded prescriptions, what is the cost of the glycerin used?

ANSWERS TO "CASE IN POINT" AND PRACTICE PROBLEMS

Case in Point 5.1

Quantity of lactic acid needed to fill $\mathcal{R}$: 1.5 g

Source of lactic acid: liquid containing 85 g/100 g; or, by using specific gravity:

$$100 \text{ g} \div 1.21 = 82.64 \text{ mL}$$

Thus, 85 g of lactic acid are in 82.64 mL of the source liquid.

By proportion:

$$\frac{85 \text{ g}}{82.64 \text{ mL}} = \frac{1.5 \text{ g}}{x \text{ mL}}, x = 1.46 \text{ mL, answer.}$$

Practice Problems

1. 0.812 g/mL
2. 8.933 g/mL
3. 1.133
4. 1.285
5. 1.300
6. 0.916
7. 1.253
8. 1.180
9. 0.863
10. 1.831
11. 1.049
12. 1.110
13. 1.250
14. 1.227
15. 0.678
16. (a) 79 g
(b) 87 g
(c) 131 g
(d) 159 g
(e) 1360 g
17. 9.2 kg
18. 7.397 or 7.4 lb
19. 4.86 kg
20. 1646.5 g
21. (a) 108.7 mL
(b) 104.17 mL
(c) 92.59 mL
(d) 58.82 mL
(e) 7.35 mL
22. 405.357 mL
23. 546.448 mL
24. 1.54 g
63.04 g
25. 258.75 g
26. 44.44 mL
27. 139.776 mL
28. 270 mg
29. 150 g
30. 11.76 mL
0.93 mL
31. 41.28 g
32. 29,702.97 mL
33. \$85.23
34. \$70.65