

CONCENTRATION UNITS

1. How many grams of CuSO_4 are required to make 650. mL of a 0.115 M solution?
2. How many grams of NaCl are required to prepare 250. mL of a 0.241 M solution?
3. How many grams of Na_2SO_4 are required to make 90.0 mL of a solution that is 0.200 M in Na^{1+} ?
4. How many mmoles of each ion are present in 325 mL of a 0.0817 M solution of $\text{K}_2\text{Cr}_2\text{O}_7$?
5. How many mmoles of chloride ion are in 55.0 mL of 0.0688 M BaCl_2 solution?
6. How many mL of a 0.338 M Na_3PO_4 are required to deliver 23.6 mmol of sodium ion?
7. How many mL of 0.124 M $\text{Ba}(\text{OH})_2$ are required to deliver 38.6 mmol of hydroxide ion?
8. How many mL of a 0.125 M aqueous solution of NaNO_3 could be made from 3.50 g of NaNO_3 ?
9. How many grams of sodium should be added to 15.0 g Hg to make a mixture in which the mole fraction of sodium is 0.800?
10. Drinking water in the USA cannot exceed 0.5 ppm mercury. What mass of mercury is present in 1.0 L of water at this concentration? What is the molar concentration of mercury?
11. The density of a 1.140 M solution of NH_4Cl at 20 °C is 1.0186 $\text{g}\cdot\text{mL}^{-1}$. What mass of water does 100. mL of this solution contain?
12. What is the mass percent sucrose in a 0.180 m aqueous solution of sucrose ($\text{C}_{12}\text{H}_{22}\text{O}_{11}$, $M_m = 342 \text{ g}\cdot\text{mol}^{-1}$)?
13. What mass of $\text{Fe}(\text{ClO}_4)_3$ is required to make 275 mL of a solution that is 0.100 M in ClO_4^{1-} ?
14. How many grams of Na_2SO_4 should be added to 285 g of H_2O to make a solution with a colligative molality of 0.500 m?
15. How many grams of CaCl_2 should be added to 50.0 g of H_2O to make a solution in which the mole fraction of Cl^{1-} is 0.150?

CHANGING CONCENTRATION UNITS

16. The label on a bottle of vinegar indicates that it is 4.2% acetic acid (CH_3COOH). If the density of the solution is 1.01 $\text{g}\cdot\text{mL}^{-1}$, what is the molarity of the solution?
17. Concentrated H_3PO_4 is 75% and has a density of 1.57 $\text{g}\cdot\text{mL}^{-1}$.
 - a) What is the molarity of concentrated phosphoric acid?
 - b) How many mL of the concentrated acid would be required to prepare 1.5 L of a 0.20 M solution of H_3PO_4 ?
18. The concentration of grain alcohol ($\text{C}_2\text{H}_5\text{OH}$) in whisky is given in ‘proof’, which is twice the percent alcohol by volume (v/v). What are the mole fraction and molality of $\text{C}_2\text{H}_5\text{OH}$ in 90 proof vodka? Assume that vodka is a solution of only $\text{C}_2\text{H}_5\text{OH}$ and water and that the volumes are additive. The density of $\text{C}_2\text{H}_5\text{OH}$ is 0.79 $\text{g}\cdot\text{mL}^{-1}$.
19. A 60/40 solder is a solution that is 60% Pb and 40% Sn. What are the two mole fractions in the solder?
20. The solubility of $\text{Mg}_3(\text{PO}_4)_2$ is 6 μM . How many ppm of *magnesium ion* are in a saturated solution?
21. What is the molality of a sucrose solution if its mole fraction is 0.025?
22. Cisplatin, $(\text{NH}_3)_2\text{Cl}_2\text{Pt}$, is a chemotherapy agent for the treatment of some cancers. Determine the mass of cisplatin in 100. mL of each of the following solutions:
 - a) 1.0 μM $(\text{NH}_3)_2\text{Cl}_2\text{Pt}$
 - b) 1.0 ppm $(\text{NH}_3)_2\text{Cl}_2\text{Pt}$
 - c) 1.0 ppm $(\text{NH}_3)_2\text{Cl}_2\text{Pt}$
23. Pure, crystalline Si is a poor conductor, but it can be converted into a p-type semiconductor by dissolving 1.0 ppm Ga in the Si crystal. This is a process called “doping” in the semiconductor industry. Given that the molar mass of Si is 28.086 and of Ga is 69.72, what is the mole fraction of Ga in the crystal? The density of the p-type Si semiconductor is 2.33 $\text{g}\cdot\text{cm}^{-3}$.
24. What is the concentration of CaCl_2 expressed as percent in an aqueous solution that is 0.820 M in CaCl_2 and has a density of 1.070 $\text{g}\cdot\text{mL}^{-1}$.
25. What is the molality of a 2.06 M solution of H_2SO_4 ($d = 1.124 \text{ g}\cdot\text{mL}^{-1}$)?

DILUTION

26. 265 mL of a 0.125 M NaCl solution is left uncovered. What is the molarity of the solution if evaporation reduces the volume to 186 mL?
27. What is the molarity of a solution prepared by adding 30.0 mL of water to 57.0 mL of a 0.114 M CuSO₄ solution? Assume additive volumes.
28. To what volume should 10 mL of 12 M HF be diluted to make 0.50 M HF?
29. What volume of an 18.0 M stock solution of H₂SO₄ is needed in order to make 100. mL of 3.0 M H₂SO₄ solution?
30. How many mL of 9.85 M H₂SO₄ are needed to prepare 500. mL of 0.0850 M H₂SO₄?
31. What is the [H¹⁺] in a solution prepared by diluting 20.0 mL of 12.0 M HCl to 350. mL?
32. What is the [H¹⁺] in a solution prepared by mixing 1.0 L of 2.0 M HCl, 1.6 L of 0.80 M HCl, 0.50 L of 3.0 M HCl, and 1.4 L of water?
33. What is the molarity of the chloride ion in a solution prepared by mixing 75 mL of 0.20 M NaCl and 55 mL of 0.15 M MgCl₂? Assume that volumes are additive.
34. 20.0 mL of 2.50 M stock solution is diluted to 50.0 mL. A 15.0-mL sample of the resulting solution is then diluted to 45.0 mL. A 20.0-mL sample of this solution is then diluted to 75.0 mL. What is the concentration of sucrose in the final solution?
35. 100.0 mL of a stock solution of hydrochloric acid was diluted to 250.0 mL. A 10.0-mL sample of the resulting solution was then diluted to 250.0 mL. The final solution was prepared by diluting 30.0 mL of this solution to 100.0 mL. A 40.0-mL sample of the final solution was titrated with 0.0887 M NaOH. If the titration required 32.6 mL of the base, what is the concentration of the original stock solution?
36. A solution, which is prepared by four consecutive 1:4 dilutions of a stock solution, has a concentration of 0.244 mM. What is the concentration of the stock solution?
37. A stock solution that is 0.4762 M undergoes the following successive dilutions: 1:3, 2:5, 1:10, and 2:15. What is the concentration of the final solution?

BEER'S LAW

38. The manganese concentration in steel can be determined spectrophotometrically by dissolving the steel in acid and oxidizing Mn to MnO₄¹⁻. The resulting solution is purple and the absorbance at 525 nm can be monitored. A standard solution that is 0.228 mM in MnO₄¹⁻ has an absorbance of 0.343 in a 1.00-cm cell. The absorbance of an unknown manganese solution in the same cell is 0.468. What is the molar concentration of Mn in the unknown solution?
39. Formaldehyde, CH₂O (M_m = 30.03 g·mol⁻¹), is an atmospheric pollutant that can be measured in aqueous solutions by reaction with 1,3,5-trihydroxy-benzene to produce a red-orange dye. A standard solution was prepared by dissolving 1.50 mL of formaldehyde gas (at 1.00 atm pressure and 25 °C) in 1.00 L of water. This solution was treated with an excess of 1,3,5-trihydroxy-benzene. A couple of milliliters of the resulting solution was placed in a spectrophotometric cell with a thickness of 1.00 cm and the absorbance was found to be 0.967 at 470 nm. A 1.00-L sample of rainwater was similarly treated and the absorbance, measured in the same cell, was determined to be 0.426. What is the concentration of formaldehyde in the rainwater? Express your answer in both molar and ppm units.
40. A 2.78x10⁻⁴ M solution has an absorbance of 0.449 at 520 nm in a 1.00-cm cell. The solvent's absorbance under the same conditions is 0.012.
- a) What is the molar absorptivity of the solute?
- b) What is the solute concentration in a solution with an absorbance of 0.368 in a 1.00-cm cell at 520 nm?

41. $\text{Ru}(\text{bpy})_3^{2+}$ (bpy = 2,2'-bipyridine) was investigated for its possible use in solar energy conversion. A solution was prepared by dissolving 58.2 mg $\text{Ru}(\text{bpy})_3(\text{ClO}_4)_2$ ($M_m = 612 \text{ g}\cdot\text{mol}^{-1}$) in enough water to make 100.0 mL of solution. However, the resulting solution absorbed too strongly at 450 nm to be measured, so 5.0 mL of the solution was diluted to 100.0 mL. The absorbance of the final solution at 450 nm in a 1.00-cm cell was determined to be 0.571.
- What is the molar absorptivity of $\text{Ru}(\text{bpy})_3^{2+}$ at 450 nm?
 - What is the concentration of $\text{Ru}(\text{bpy})_3^{2+}$ in a solution with an absorbance of 0.885 at 450 nm?
42. Ammonia can be determined spectrophotometrically by reaction with phenol ($\text{C}_6\text{H}_5\text{OH}$) in the presence of OCl^- ion. The product of the reaction absorbs at 625 nm. The nitrogen in a protein was determined in the following manner.
- Reference: A solution was made by dissolving 10.0 mg NH_4Cl in water. Phenol and KOC were then added. After reaction, the solution was diluted to 1.00 L. 20.0 mL of the solution was then diluted to 100.0 mL, and the absorbance was found to be 0.168 at 625 nm. What is the molar absorptivity of the product of the reaction between ammonia and phenol in the presence of hypochlorite?
 - Sample: All of the nitrogen in 5.02 mg of a protein was converted into ammonia. Then phenol and KOC were added. After the reaction, the solution was diluted to 500. mL and the absorbance was measured to be 0.564 at 625 nm. How many mmoles of nitrogen were in the original sample? What is the mass percent of nitrogen in the protein?

COLLIGATIVE PROPERTIES

43. What is the colligative molality of a solution prepared by dissolving 15.2 g of AlCl_3 ($M_m = 133.3 \text{ g}\cdot\text{mol}^{-1}$) in 155 mL of water?
44. List the freezing points of 0.10 m aqueous solution of the following in decreasing order. Explain your reasoning.
- $\text{C}_{12}\text{H}_{22}\text{O}_{11}$ CaCl_2 CaSO_4
45. What is the freezing point of a 0.11 m aqueous CaCl_2 solution?
46. What is the osmotic pressure of a 0.056 M aqueous NaCl at 298 K?
47. What is the osmotic pressure of a 0.20 M CaCl_2 solution at 298 K?
48. As a very rough general rule, increasing the temperature of a reaction by 10 °C doubles the rate of reaction. Approximately how many grams of salt should be added to 1.5 qts (~ 1.5 L) of water to increase the boiling water by 10 °C? Would this be a satisfactory way in which to reduce the time required to make "boiled potatoes"?
49. A solution is prepared by dissolving 1.0 g of CaCl_2 in 100. mL of water to produce a solution with a density $1.1 \text{ g}\cdot\text{mL}^{-1}$.
- What is the vapor pressure of the solution at 20 °C? The vapor pressure of water at 20 °C is 17.5 mm Hg?
 - What is the boiling point of the solution?
 - What is the freezing point of the solution?
 - What osmotic pressure would develop at 25 °C when the solution is placed in contact with pure water at a semipermeable membrane?
50. The colligative molality of seawater is about 1.10 m, and its density is about $1.05 \text{ g}\cdot\text{mL}^{-1}$.
- What is the vapor pressure of the solution at 20 °C? The vapor pressure of water at 20 °C is 17.5 mm Hg.
 - What is the normal boiling point of seawater?
 - What is the freezing point of seawater?
51. The colligative molarity of living cells is typically 0.3 M. What osmotic pressure would develop when the cells are placed in pure water at 37 °C? What effect would this have on the cell?
52. Pepsin is the principal digestive enzyme of gastric juice. A 1.50-g sample of pepsin is dissolved in enough water to make 5.00 mL of solution. The osmotic pressure of the solution is found to be 0.213 atm at 25 °C. What is the molar mass of pepsin?
53. 15.8 mg of a protein is dissolved in enough water to make a 5.00-mL solution. What is the molar mass of the protein if the osmotic pressure of the solution at 15 °C is 4.65 torr?

54. A solution is prepared by dissolving 1.63 g of an unknown organic compound in 15.00 g of cyclohexane. What is the molar mass of the compound if the solution has a melting point of $-5.1\text{ }^{\circ}\text{C}$? See Table 2.4 for information about cyclohexane.
55. Vitamin K is involved in normal blood clotting. When 1.00 g of vitamin K is dissolved in 20.0 g of camphor, ($k_f = 40.0\text{ }^{\circ}\text{C}\cdot\text{m}^{-1}$) the freezing point of the solution is lowered by $4.43\text{ }^{\circ}\text{C}$. What is the molar mass of vitamin K?

SOLUTION STOICHIOMETRY

56. Alcohol levels can be determined by reaction with dichromate (breathalyzer).

$$\text{C}_2\text{H}_5\text{OH}(\text{l}) + 2\text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 16\text{H}^+(\text{aq}) \rightarrow 4\text{Cr}^{3+}(\text{aq}) + 11\text{H}_2\text{O}(\text{l}) + 2\text{CO}_2(\text{g})$$
 What is the alcohol level expressed in parts per thousand of a blood plasma if a 30.0-g sample of plasma requires 27.43 mL of a 0.02226-M solution of $\text{K}_2\text{Cr}_2\text{O}_7$ for complete reaction?
57. What is the concentration of the excess reactant in a solution prepared by mixing 25.0 mL of 0.242 M HCl with 36.3 mL of 0.167 M $\text{Ba}(\text{OH})_2$? Is this solution acidic, basic or neutral?
58. Given the *unbalanced* chemical equation:

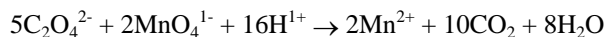
$$\text{Al}(\text{OH})_3(\text{s}) + \text{HCl}(\text{aq}) \rightarrow \text{AlCl}_3(\text{aq}) + \text{H}_2\text{O}(\text{l})$$
 How many mL of 2.00 M HCl are required to react completely with 50.0 g of $\text{Al}(\text{OH})_3$?
59. Determine the amount of precipitate that will form if 50.0 mL of 0.100 M $\text{Na}_2\text{SO}_4(\text{aq})$ and 100. mL of 0.300 M BaCl_2 are mixed.
60. Construct the reaction table for the *net* reaction resulting when 45.0 mL of 0.0886 M AgNO_3 and 35.0 mL of 0.106 M K_2CrO_4 are mixed.
 a) What mass of precipitate would form?
 b) Assume additive volumes and determine the concentration of the excess reactant after the reaction is complete?
61. Construct the reaction table for the *net* reaction of 36.6 mL of 0.0668 M FeCl_3 and 24.2 mL of 0.100 K_2S .
 a) What mass of Fe_2S_3 precipitates?
 b) What is the concentration of the excess reactant after complete reaction? Assume additive volumes.

MISCELLANEOUS PROBLEMS

62. Trichloroethylene, C_2HCl_3 is used as a dry cleaning solvent and an industrial extraction agent. The EPA (Environmental Protection Agency) has set a limit of 5.0 ppb C_2HCl_3 in drinking water. Assuming that the average person consumes 2.0 L of drinking water in a day, what is the maximum mass of trichloroethylene to which a person could be exposed through drinking water? Drinking water has a density of $1.0\text{ g}\cdot\text{mL}^{-1}$.
63. Given the *unbalanced* chemical equation:

$$\text{Zn}(\text{s}) + \text{HCl}(\text{aq}) \rightarrow \text{H}_2(\text{g}) + \text{ZnCl}_2(\text{aq})$$
 If 130. mL of $\text{HCl}(\text{aq})$ reacts with an excess of Zn, the reaction produces 7.00 L of $\text{H}_2(\text{g})$ at 273 K and 1.00 atm. What is the molarity of the HCl?
64. A 0.250 m aqueous solution of $\text{Co}(\text{NH}_3)_4\text{Cl}_3$ freezes at $-0.93\text{ }^{\circ}\text{C}$. Determine the van't Hoff factor for the complex ion.
65. A solution is prepared by dissolving 5.863 g of impure NaOH in sufficient water to make 1.000 L of solution. The solution is added to a buret and used to titrate 25.00 mL of a 0.1173 M solution of HCl.
 a) What is the molarity of the NaOH solution if the titration requires 28.04 mL of base.
 b) What is the percent purity of the original NaOH sample?
66. A 0.5843-g sample of impure $\text{Ca}(\text{OH})_2$ is dissolved in 50.00 mL of water. 20.00 mL of the resulting solution is then titrated with 0.1164 M HCl. What is the percent purity of the $\text{Ca}(\text{OH})_2$ if the titration requires 22.18 mL of acid?

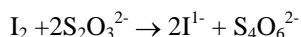
67. A 10.00-mL sample of blood was diluted to 100.00 mL. 10.00 mL of the resulting solution was analyzed for calcium by precipitating all of the calcium as calcium oxalate, CaC_2O_4 . The solid CaC_2O_4 was then re-dissolved in H_2SO_4 and titrated with KMnO_4 . What is the Ca^{2+} ion concentration in the blood sample expressed as (milligrams Ca^{2+})/(mL blood) if the endpoint was reached with the addition of 1.14 mL of 0.00886 M KMnO_4 ?



68. Vitamin C or ascorbic acid ($\text{C}_6\text{H}_8\text{O}_6$) can be analyzed by first oxidizing it with an excess of I_2 by the following reaction:

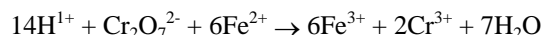


and then determining the amount of excess I_2 by titration with $\text{S}_2\text{O}_3^{2-}$.



A tablet that is supposed to contain 500-mg of vitamin C was dissolved in water and 100.00 mL of 0.06246 M I_2 was added. After complete oxidation of the ascorbic acid, the solution was titrated with $\text{S}_2\text{O}_3^{2-}$. How many milligrams of vitamin C were in the tablet if the titration required 63.69 mL of 0.1127 M $\text{K}_2\text{S}_2\text{O}_3$?

69. All of the iron in 1.314 g of an ore was converted to Fe^{2+} , which was then analyzed by titration with dichromate. What is the mass percent of iron in the ore if 38.64 mL of 0.02063 M $\text{K}_2\text{Cr}_2\text{O}_7$ was required to reach the equivalence point? The chemical equation for the titration is



70. The chloride ion concentration in a sample of seawater was analyzed by titration with 0.1126 M AgNO_3 to precipitate AgCl . What is the chloride ion concentration in a 10.00-mL sample, if the titration required 46.78 mL of 0.1126 M AgNO_3 to reach the endpoint? If the density of seawater is $1.012 \text{ g}\cdot\text{mL}^{-1}$, what is the mass percent of chloride ion in the sample?
71. The concentration of a stock solution of Rhodamine B, a commercial dye ($\epsilon = 1.060 \times 10^5 \text{ M}^{-1}\cdot\text{cm}^{-1}$ at 543 nm) is determined spectrophotometrically, but the absorbance of the stock solution was too great to read on a spectrometer, so 15.00 mL of the solution was diluted to 250.00 mL. The resulting solution was still too concentrated, so 10.00 mL of that solution was diluted to 500.00 mL, but the solution was still too concentrated. However, a dilution of 25.00 mL of the resulting solution to a final volume of 500.00 mL provided an acceptable solution with an absorbance of 0.1814 in a 1.000-cm cell. What is the concentration of the stock solution? What volume of stock solution would be required to make 2.000 L of a solution with an absorbance of 1.000 in a 1.000-cm cell?
72. What is the iron(III) concentration in an acidified solution if adding an excess of hydroxide to 20.00 mL of the solution produced 181 mg of $\text{Fe}(\text{OH})_3$?
73. How many grams of NaCl must be added to 120 mL of water at 25 °C to prepare a solution with a vapor pressure of 20.0 torr? At 25 °C, the density of water is $1.0 \text{ g}\cdot\text{mL}^{-1}$, and its vapor pressure is 23.8 torr.