Further examples:

1. You dissolve 8,00 g of solid sodium hydroxide NaOH in 0,500 kg of water. The density of the resulting solution is ρ = 1,05 g mL^{-1}.

Calculate
a) The molar concentration *c* of NaOH in the solution.
b) The molality *b* of NaOH in the solution.
c) The mass fraction *w* of H_2O in the solution.
d) The molar fraction *x* of Na^+ in the solution

Molar mass of NaOH: 22,990 + 15,999 + 1,008 = 39,997 ~ 40 g/mol
Molar mass H_2O: 15,999 + 2 . 1,008 = 18,015 ~ 18
Mass of solute: m_{NaOH}= 8 g NaOH
Mass of solvent: m_{H2O} = 500 g
Total mass of solution: m_{tot} =508 g
Amount of substance n_{NaOH}: 8/40 = 0,2 mol NaOH,
Volume V_{tot}: 508/1,05 = 483,81 mL = 0,48381 L
Amount of H_2O in 500 g : n_{H2O} = 500/18 = 27,78

a) The molar concentration of NaOH in the solution.
c_{NaOH} = n/V → 0,2/0,48381 → 0,413385 → 0,413mol/L

b) The molality of NaOH in the solution.
b_{NaOH} = n/kg_{slv} → 0,2/0,5 → 0,400 mol/kg_{slv}

c) The mass fraction of H_2O in the solution.
w_{H2O}: m_{H2O} / m_{tot} = 500/508 = 0,984252 → 0,984→ 98,4%

d) The molar fraction *x* of Na+ in the solution
Amount of substance Na^+ = amount of substance OH^- = amount of substance NaOH = 0,2 mol
Amount H_2O = 27,78
Total amount of substance: 27,78 + 0,2 + 0,2 = 28,18
x_{Na+} = 0,2/28,18 = 0,71%

2. You dissolve 10,00 g of solid calcium chloride in 0,600 kg of water. The density of the resulting solution is ρ = 1,03 g mL^{-1}.

Calculate
a) The molar concentration *c* of $CaCl_2$ in the solution.
b) The molarity *b* of $CaCl_2$ in the solution.
c) The mass fraction *w* of $CaCl_2$ in the solution.
d) The molar fraction *x* of Cl^- in the solution

Molar mass $CaCl_2$: 40,078 + 2 . 35,453 = 110,984 ~ 111 g/mol
Molar mass H_2O: 15,999 + 2 . 1,008 = 18,015 ~ 18
Mass of solute: m_{CaCl2}= 10 g
Mass of solvent: m_{H2O} = 600 g
Total mass of solution: m_{tot} =610 g

Amount of substance n_{CaCl2}: 10/111 = 0,0901 mol CaCl2,
Volume V_{tot}: 610/1,0 = 592,23 mL = 0,59223 L
Amount of substance H_2O in 600 g : n_{H2O} = 600/18 = 33,333

a) The molar concentration of $CaCl_2$ in the solution.
c_{CaCl2} = n/V → 0,0901/0,59223→ 0,15214 → 0,152mol/L

b) The molarity of $CaCl_2$ in the solution.
b_{CaCl2} = n/kg_{slv} → 0,0901/0,6 → 0,150 mol/kg_{slv}

c) The mass fraction of $CaCl_2$ in the solution.
w_{CaCl2}: m_{CaCl2} / m_{tot} = 10/610 = 0,016393 → 0,0164 → 1,64%

d) The mole fraction x of Cl^- in the solution
Amount of substance Cl^- = 2 x amount of substance $CaCl_2$ = 2 x 0,0901 = 0,1802 mol
Amount of substance Ca^{2+} = 0,0901
Amount H_2O = 33,333
Total amount of substance: 33,333 + 0,0901 + 0,1802 = 33,6033
x_{Cl^-} = 0,1802/33,6033 = 0,005362 = 0,536%

3. A NaCl solution contains NaCl with a mass fraction w = 0,060.
The density of the solution is 1,0389 g/mL.
a) What is the molar concentration of NaCl in the solution?
Assumption:
V_{tot} = 1L
m_{tot} = V. ρ = 1038,9 g
m_{NaCl} = w . m tot = 0,06 . 1038,9 = 62,334g
M_{NaCl} = 22,990 + 35,453 = 58,443 g/mol
n_{NaCl} = m/M = 62,334 / 58,443 = 1,06658 mol
c_{NaCl} = n/V = 1.06658/1 = 1,1 mol/L

b) How much water do you have to add to 100 mL of the solution to get a solution with a mass fraction of w = 1%.
m_{NaCl} = 100 . 1,0389 . 0,06 → 6,2334 g
m_{NaCl} ~ 1% → 100%: 6,2334 . 100 = 623,34 g solution
➔ add 623,34 – 100 . 1,0389 = 519,45 → 500 g Water

4. A solution contains 12,0 g nitric acid and 36,0 g water.
The density of the solution is 1,100 g/mL.
a) What is the molar concentration of HNO_3 in the solution?
V = m/ρ = 48,0/1,100 = 43,636 mL;
M_{HNO3} = 1,008 + 14,007 + 15,999 . 3 = 63,012 g/mol
n = 12,0/63,012 = 0,190 moles;
c = n/V = 0,190/43,636 x 1000 = 4,354 mol/L
c =4,35 mol/L
b) What is the mass fraction of HNO_3 in the solution?
x = 12,0 /(12,0 + 36,0) = 0,250

5. How many grams of NaCl do you need to dissolve in 100 mL of water in order to obtain a NaCl solution with *w* = 0,150. Water has a density of 1,000 kg/L. Note the significant digits in the result!

$w = m_{NaCl}/(m_{NaCl} + m_{H2O})$
$m_{NaCl} = x$
m_{H2O} = 100 mL x 1,000 g/mL = 100g
$w = x/(x+100) = 0,15 \Rightarrow x = 17,647$ g

6. 0,500 L of an aqueous soulution with a density of 1,05 g/mL contain 11,1 g calcium chloride.

a) what is the molar concentration of $CaCl_2$?
n = 11,1/110,98 = 0,10001442 mol
in 500 ml → 0,200 mol/L $CaCl_2$

b) what is the molar concentration of chloride ions?
1 mol $CaCl_2$ → 2 mol Cl^- → 0,400 mol/L Cl^-

c) what ist he mass fraction *w* of $CaCl_2$ in the solution?
M = 500 x 1,05 → 525 g total solution
w = *m*/*M* → 11,1/525 → 0,0211 or 2,11%

d) How much water hast o be added to dilute the solution to a mass fraction of 1% ?
11,1 g …. 1% → total wight of the diluted solution 1110g
525 g already present → add 585 g water

7. To prepare a saturated KCl solution at 20°C, 34,35 g KCl must be dissolved in 100,0 g water. The density of this solution ρ_{20} = 1,174 g/mL. Calculate the molar concentration and the molality of this solution.

34,35 g KCl + 100 g H_2O = 134,35 g solution
M_{KCl} = 74,55 g/mol
V = 134,35/1,174 = 114,4 mL
m_{KCl} = 34,35/74,55 = 0,4608 mol
c_{KCl} = 0,4608/0,1144 = **4,028 mol/L**
b_{KCl} = 0,4608/0,1 = **4,608 mol/kg$_{slv}$**

8. 10,0 g $CoCl_2.2H_2O$ dissolved in alcohol and made up to $5,00.10^2$ mL.

a) What is the concentration of Co^{2+} in the solution?
n_{CoCl2} = 10,0/165,869 = 0,060288 mol
n_{Co2+} = 0,060288 , V = 500 mL
c_{Co} = n/V = 0,060288/0,5 = **0,121 mol/L**

b) What is the concentration of Cl^- in the solution?
n_{CoCl2} = 10,0/165,869 = 0,060288 mol
n_{Cl-} = 0,060288*2 = 0,12057; V = 500 mL
c_{Cl} = n/V = 0,12057/0,5 = **0,241 mol/L**

9. Calculate the molar concentration of the following solutions:
   a) a) 29,22 g NaCl in 250 mL aqueous solution
      M_{NaCl} = 58,44 g/mol ; ρ = 1.10 g/mL

      n_{NaCl} = 29,22/58,44 = 0,5 mol; V = 250mL
      c_{NaCl} = 0,5/0,25 = **2,0 mol/L**
   b) 0,600 mol H_2SO_4 in 1,50 kg H_2O total solultion
      ρ = 1,025kg/L, M_{H2SO4} = 98,079g/mol
      n_{H2SO4} = 0,600 mol; V= 1,50/1,025 = 1,4634 L
      c_{H2SO4} = 0,6/1,4634 = **0,41 mol/L**

   c) 25 % alcohol solution (mass fraction in w%)
      ρ = 0,96339 g/mL; M_{C2H5OH} = 46,07
      V = 1L : m_{alc} = 0,25*963,39 = 240,8g
      n_{alc} = 240,8/46,07 = 5,2 mol;
      c_{alc} = 5,2 mol/L

10. Calculate the molality *b* of the following solutions:
   a) 29,22g NaCl in 250 mL aqueous solution
      M_{NaCl} = 58,44g/mol ; ρ = 1,10 g/mL
      n_{NaCl} = 29,22/58,44 = 0,5 mol;
      m_{sol} = 250 * 1,1 = 275g; m_{slv} = 275 – 29,22 = 245,78g
      b_{NaCl} = 0,5/0,24578 = **2,03 mol/kg$_{LM}$**

   b) 0,600 mol H_2SO_4 in 1,50 kg H_2O aqueous solution
      ρ = 1,025kg/L, M_{H2SO4} = 98,079g/mol
      n_{H2SO4} = 0,60 mol; m_{H2SO4} = 0,6*98,079 = 58,85 g; m_{slv} = 1500 – 58,85 = 1441,15g
      b_{H2SO4} = 0,6/1,44115 = **0,416 mol/kg$_{slv}$**

   c) 25,0 % alcohol solution (mass fraction in w%)
      ρ = 0,96339 g/mL; M_{C2H5OH} = 46,07
      1L : m_{alc} = 0,25*963,39 = 240,8g
      n_{alc} = 240,8/46,07 = 5,2 mol; m_{slv} = 0,75*0,96339 = 0,7225 kg
      b_{alc} = 5,2/0,7225 = **3,76 mol/kg**

11. Calculate the molar fraction *x* of the following solutions:

   a) 29,22g NaCl in 250 mL aqueous solution
      M_{NaCl} = 58,44g/mol ; ρ = 1,10 g/mL; M_{H2O} = 18,015
      n_{NaCl} = 29,22/58,44 = 0,5 mol;
      m_{sol} = 250 * 1,1 = 275g; m_{slv} = 275 – 29,22 = 245,78g;
      n_{sol} = 245,78/18,015 = 13,64; n_{tot} = 13,64 + 0,5 = 14,14
      x_{NaCl} = 0,5/14,14 = **0,0353 (mol/mol)**

   b) 0,600 mol H_2SO_4 in 1,50 kg H_2O aqueous solution
      ρ = 1,025kg/L, M_{H2SO4} = 98,079g/mol; M_{H2O} = 18,015
      n = 0,60 mol; m_{H2SO4} = 0,6*98,079 = 58,85 g;
      m_{slv} = 1500 – 58,85 = 1441,15g; n_{slv} = 1441,15/18,015 = 80 mol
      n_{tot} = 80 + 0,600 = 80,6
      x_{H2SO4} = 0,6/80,6 = **0,00744 (mol/mol)**

c) 25,0 % alcohol solution (mass fraction in w%)
ρ = 0,96339 g/mL; M_{C2H5OH} = 46,07; M_{H2O} = 18,015
m_{alc} = 0,25*963,39 = 240,8g
n_{alc} = 240,8/46,07 = 5,2 mol;
m_{slv} = 0,75*0,96339 = 0,7225 kg; n_{H2O} = 722,5/18,015 = 40,11 mol
n_{tot} = 5,2 + 40,11 = 45,31
x_{alc} = 5,2/45,31 = **0,115 (mol/mol)**

12. 97,1 g Potassium chromate are dissolved in 900,8 g water.
The density of the solution is 1,05 kg/L. Calculate the concentration of K_2CrO_4 as

a) molar concentration *c*
b) molality *b*
c) mass fraction *w*
d) molar fraction *x*

amount of substance n_{K2CrO4} : 97,1/ 194,188 = 0,5000 mol
amount of substance n_{H2O} : 900,8/18,015 = 50,00 mol
total amount of substance n_{ges} : 0,5000 + 50,00 = 50,50 mol
mass of the solution *m* : 97,1+900,8 = 997,9 g = 0,9979 kg
Volume solution *V* : 0,9979/1,05 = 0,9504 L

a) molar concentration
c_{K2CrO4} = n/V = 0,500/0,9504 = **0,526 mol/L K_2CrO_4**
b) molality
b_{K2CrO4} = n/m_{LM} = 0,500/0,9008 = **0,555 mol/kg_{H2O}**
c) mass fraction
w_{K2CrO4} = m/m_{ges} = 97,1/997,9 = 0,0973 = **9,73%**
d) molar fraction
x_{K2CrO4} = n/n_{ges} = 0,500/50,50 = **0,0099**

13. Concentrated (fuming) hydrochloric acid has a composition of w = 37% and a density at 20°C of 1.19 g/mL. Prepare 2 L of diluted hydrochloric acid with the molar concentration c = 2.00 mol/L.
M_{HCl} = 36.461 g/mol.
a) How much hydrochloric acid do you need to use (in g) ?
b) To what volume of HCl would this correspond?
c) How much water would you need to use? The density of hydrochloric acid @ 2mol/L is 1,03 g/mL

a) c_{2HCl} =2 mol/L
m_{2HCl} = 2 . 2 . 36,461 = 145,844 g pure HCl
m_{1HCL} = 145,844/ 0,37 = **394,17 = 390 g**
b) V_{1HCl} = 394,17/1,19 = 331,2377 = 330 mL
c) m_{2HCl} = V_{2HCl} x ρ_{2HCl} = 2 x 1,03 = 2060 g
m_{H2O} : 2060 – 394,17 = **1665,83 g**

14. At 20°C, a saturated sodium chloride solution has a molar concentration of c=6.00 mol/L and a density of 1.18 g/mL.

a) How much water in g must be added to 500,0 g NaCl in order to produce a saturated solution?
n_{NaCl} = 500/58,44 =8,55578 mol
c_{satsol} : 6/1 = 8,556/V V = 8,556/6 = 1,4259 L
m_{satsol} = V · ρ m = 1,4259 · 1,18 = 1,6826 kg
m_{H2O} = 1682,6 - 500 =1182,6 g water = $1{,}18 \cdot 10^3$ g H_2O

b) Calculate the mass fraction and the molar fraction of NaCl in this solution
w_{NaCl} = 500/1682,6 = 29,71% = 29,7%
x_{NaCl} = 8,5578/(8,5578 + 1182/18,015) = 0,115

c) How much water do you have to add to 1,00 L of this solution in order to produce a NaCl solution @ 0,100 mol/L?
$c_1.V_1 = c_2.V_2$
V_2 = 6.1/0,1 = 60 L → add 59 L

15. 200,0 mL of a $CaCl_2$ solution with c= 1,50 mol/L and 300,0 mL of a NaCl solution with c= 3,00 mol/L are mixed. Calculate the following concentrations of the mixture in respect to:

a) Cl^-- ions
b) Ca^{2+} - ions
c) Na^+ - ions

a) total volume: 200 + 300 = 500 mL
n_{CaCl2} = 1,5 . 0,2 = 0,300
n_{NaCl} = 3 . 0,3 = 0,900
b) n_{Cl-} = 2 . 0,3 + 0,9 = 1,5
c_{Cl} = 1,5/0,5 = 3,00 mol/L
c) c_{Ca} = 0,3/0,5 = 0,600 mol/L
c_{Na+} = 0,9/0,5 = 1,80 mol/L.

16. A solution of hydrochloric acid with the mass fraction of *w*=10,0% has a density of 1,0474 g/mL at 20°C.

a) what ist he molar concentration c .
M_{HCl} = 36,461 g/mol
V = 1 L → 1047,4 g
m_{HCl} = w . m_{tot} = 0,1 . 1,0474 = 104,74g HCl
n_{HCl} = m/M = 104,74/36,461 = 2,8726 mol
c_{HCl} = n/V = 2,8726/1,00 = **2,87 mol/L**
b) 0,500 L oft he solution above is diluted to 10,0 L total volume. What ist the new concentration? .
$c_1 . V_1 = c_2 . V_2$
c_2 = 0,5 · 2,8726/ 10 = **0,14363 mol/L**

17. A maximum of 58 g HCl gas can be dissolved in 100,0 g water. The density of the resulting solution is 1,19 g/mL.

a) What is the molar concentration c of the resulting hydrochloric acid?

m = 158 g solution → V = 158 / 1,19 = 132,77 mL

n_{HCl} = 58 / 36,461 = 1,5907 mol

c_{HCl} = n / V = 11,981 = 12 mol/L HCl

b) Using the solution above 50,0 L diluted hydrochloric acid should be produced with a molar concentration of c_2 = 0,250 mol/L. How much wáter and how much concentrated solution are needed?

$c_1.V_1 = c_2.V_2$

11,981. V_1 = 0,250 . 50

V_1 = 0,250 . 50 / 11,978 = 1,044 ..... **1,0 L conc. HCl**

V_{H2O} = 50L – 1,044 = 48, 956 .... **49 L water**