Mass ⇄ Mole Interconversion.

A. Introduction

This handout should be done after completing Molar Mass and Dimensional Analysis, especially Part D. (You will also need to use some metric prefixes and exponential notation. These topics are covered in optional handouts.) It must be done before Molarity.

There is a quiz after each of the major sections. The quiz after Sect B is optional. (The idea is to give you flexibility. If you prefer to do one small piece at a time, this quiz is a useful checkpoint. On the other hand, if you are comfortable "whizzing by" this one, that's ok, too.)

B. Mass ⇄ mole interconversions: simple

An easy way to measure the amount of a chemical is to weigh it (measure the mass). However, chemists are often interested in knowing the amount of a chemical in moles; balanced chemical equations tell the amount of each chemical involved in a reaction -- in moles. It is important to be able to convert between the practical measurement (mass) and the underlying relevant measurement (moles).

You know how to calculate the molar mass (formula weight) of a chemical. You also know how to apply the method of dimensional analysis to guide you through problems involving unit conversions. Since the units of the molar mass are g/mole, mass ⇄ mole interconversion problems are a simple application of dimensional analysis.

Examples

B1. How many grams are in 2.00 moles of NaCl?

$$2.00\ \cancel{\text{mol}} \times \frac{58.44\ \text{g}}{\cancel{\text{mol}}} = 117\ \text{g}$$

B2. How many moles are in 117 g of NaCl?

$$117\ \cancel{\text{g}} \times \frac{\text{mol}}{58.44\ \cancel{\text{g}}} = 2.00\ \text{mol}$$

How many decimal places. Revisited. We discussed this briefly in Molar Mass. At that point, the main advice was to try to be consistent. There is nothing inherent in the molar mass calculation alone to suggest any particular calculation precision. But now we have some guidance. In mass ⇄ mole interconversions you are given one piece of data and asked to calculate something from it. Data is an experimental measurement (actual or implied), and thus has a measurement uncertainty, or precision. The number of significant figures (SF) shown in the measurement is a simple way to indicate the precision. The precision of the given data should guide your calculation precision.

Example

B3. Convert 2.46 g (of something) to moles. The measurement "2.46 g" was (apparently) measured to the nearest 0.01 g; that is implied by the way the measurement is written. The measurement is "good" to (about) 0.01 out of 2.46. The measurement is shown to three significant figures. A simple rule of thumb for multiplication and division is to maintain a consistent number of significant figures; this way, the precision of calculated results will be consistent with the precision of measured data.

In the g ⇄ mole conversion examples above (B1 & B2), the data was given to three (SF); 2.00 mol and 117 g each have 3 SF. Therefore, both calculations were done to three SF. (An extra, readily available, digit was used in the molar mass, to minimize possible rounding errors.)

> (This assumes, of course, that the requester did properly state the intended precision. Unfortunately, in the real world this is not always so. A person may ask you for 3 moles, and not make clear at all whether they want 3, 3.0 or 3.00 moles. No calculation rule can solve this communication problem.)

Problems. Show clear work for each problem. (Try to show proper number of SF -- especially if this is a practical issue for you.)

1. How many grams are in 3.52 moles of sodium phosphate, Na_3PO_4?
2. How many moles are in 225 g of potassium iodide, KI?
3. You need 0.615 moles of sodium hydrogen carbonate (sodium bicarbonate), $NaHCO_3$. How much will you weigh out?
4. 542 g of aluminum sulfate, $Al_2(SO_4)_3$, is how many moles?
5. Convert 2.56 moles of nickel chloride, $NiCl_2$, to grams.
6. 2.50 moles of ethyl alcohol, C_2H_5OH, is how many grams?
7. Convert 1000 g of ammonium sulfate, $(NH_4)_2SO_4$, to moles.
8. You have 35.2 g of barium hydroxide, $Ba(OH)_2$. How many moles is that?

C. Mass ⇄ mole interconversions: complex

Harder cases? Fundamentally, there aren't any. So long as you recognize that the molar mass is the direct conversion factor between grams and moles, dimensional analysis guides you to a direct one step set-up.

The following problems are harder, but they do not introduce any new ideas. The basic mass ⇄ mole interconversion is the same. There are some other features, but they are things you have seen before. Use the problems in this section as a chance to review, reinforce, and tie together several topics. Ask about issues that bother you, whether from this handout or earlier ones.

Problems. Since these problems bring together a variety of features, I suggest that you do all of them -- before taking the quiz. I encourage you to turn these in, so I can look over the work. In a sense, all of these deserve *; however, I've marked only a few, to highlight new issues being raised.

* 9. How many milligrams are in 0.0025 mole of potassium bromide, KBr?
10. How many mmol (millimoles) are in 1.00 g of sodium nitrate, $NaNO_3$?
11. 12.0 moles of barium nitrate, $Ba(NO_3)_2$, is how many kilograms?
12. 19.5 kg of potassium hydrogen phosphate, K_2HPO_4, is how many moles?
* 13. Convert 1.25 mmol of acetic acid, CH_3COOH, to mg.
14. You want 0.500 moles of cobalt chloride, $CoCl_2$. How many g do you need?
* 15. You want 0.500 moles of cobalt chloride. How many g do you need, if the available form is $CoCl_2 \cdot 6H_2O$?
16. 25 g of magnesium sulfate, $MgSO_4$ is how many moles?
17. 25 g of magnesium sulfate heptahydrate, $MgSO_4 \cdot 7H_2O$, is how many moles?
18. A procedure calls for you to add 2.0 g of anhydrous sodium carbonate, Na_2CO_3, to an aqueous solution. How many moles of sodium carbonate is that?
* 19. Continuing from the previous question… You check the stockroom and find that the only sodium carbonate you have is the decahydrate. How would you change the instructions? That is, how much of the hydrated salt would you use?
20. A procedure calls for you to add 0.50 g of anhydrous sodium sulfate, Na_2SO_4, to an organic solvent as a dehydrating agent (i.e., to remove traces of water from the organic solvent). How many mmol of sodium sulfate is this?
* 21. Continuing… Your stock of sodium sulfate is the decahydrate. How much of this would you use? (Think about the situation for a moment, before doing any more calculations.)
* 22. The blood protein hemoglobin has a molar mass of about 64,500. 1.00 g of hemoglobin is how many moles?
23. Continuing… How many µmol is that?
24. The genetic material of the bacterium Escherichia coli is a single DNA molecule, with molar mass about 3×10^9. If you had a nanomole of this chemical, how much would it weigh?

D. Answers

(In parentheses after each answer is the molar mass needed in the calculation, in g/mol.)

Sect B

1. 577 g (163.94 g/mol)	2. 1.36 mol (166.00)
3. 51.7 g (84.01)	4. 1.58 mol (342.17)
5. 332 g (129.59)	6. 115 g (46.07)

7. 7.57 mol (132.15) 8. 0.205 mol (171.35)

With one exception, the data for the problems in Sect B were given to 3 significant figures (SF), so the answers are shown to 3 SF. (However, molar masses are shown to whatever SF are readily available. It is easiest to keep extra digits until the end; worrying about SF for molar masses is usually not worthwhile.)

For #7, the SF of the data is ambiguous. The number 1000 might reasonably have 1-4 SF; no way to tell. I showed the answer here to 3 SF, more or less arbitrarily, but any properly rounded value with 1-4 SF is ok.

Sect C

9. 3.0×10^2 mg (119.00). Note the need to write the answer in scientific notation to make it clear that there are only 2 SF.
10. 11.8 mmol (85.00)
11. 3.14 kg (261.32) 12. 112 mol (174.18)
13. 75.1 mg (60.05) [The logical way to do this is to show a conversion between mol and mmol and a conversion between g and mg. But at some point you may suspect -- or realize -- that the molar mass is not only in g/mol, but also in mg/mmol or kg/kmol. In effect, the metric prefix can be canceled, top and bottom. To convince yourself, go through the conversion explicitly. Choose a chemical, and convert its molar mass from g/mol to mg/mmol. This is sometimes a useful shortcut, if you remember it. But if you don't, just use the separate conversions. A virtue of dimensional analysis is that it does not give great rewards for shortcuts; logical plodding is always ok.]
14. 64.9 g (129.83) 15. 119 g (237.93)
16. 0.21 mol (120.38) 17. 0.10 mol (246.49)
18. 0.019 mol (105.99)
19. 5.4 g (286.15) (Why? You want the same number of moles of the sodium carbonate.)
20. 3.5 mmol (142.05)
21. Well, in this case the substitution would not be possible. The purpose of using the specified anhydrous salt is for water removal. The anhydrous salt picks up water, forming the hydrate, which is more stable (a common situation for many hydrates). The hydrated salt would not work. This is a special case. More commonly, as in the earlier problem, the salt is going to be added to water; in those cases, it doesn't really matter which form you add, so long as you adjust the amount to compensate for the water. [In case you did the calculation anyway, the calculated amount of the decahydrate would be 1.1 g (322.21).]
22. 1.55×10^{-5} mol 23. 15.5 µmol 24. 3 g