Using mole calculations to solve problems

Learning objectives

1 Recall how to use simple mole calculations to calculate masses, moles, or relative formula masses.

2 Practice rearranging equations.

3 Develop confidence in decoding complex word problems.

Introduction

Mole calculations are an important tool for many kinds of people working in the sciences. Pharmacists need to identify the active ingredient in medicinal drugs, biologists use chemicals in analysis of living things and need to prepare their solutions, and chemists need to calculate the amounts of reactants they need when they carry out chemical reactions. Mole calculations can also help us to identify unknown substances.

You will have already been introduced to mole calculations. You will continue to use the same tools post-16 but embedded in more complex problems. This worksheet is designed to refresh your memory of simple mole calculations and give you opportunities to use these tools to solve more complex problems.

Moles, mass, and relative formula mass

The relationship between moles, mass and Mr can be represented by this equation:

$$mol = \frac{mass}{Mr}$$

Part 1: Working out the moles from the mass of a known substance

Worked examples

How many moles of ethene (C_2H_4) are there in 1.4 kg?

$$\boldsymbol{mol(C_2H_4)} = \frac{mass(C_2H_4)}{Mr(C_2H_4)}$$

- Identify the relative molecular mass (Mr) using the periodic table.

$$Mr(C_2H_4) = 12 \times 2 + 1 \times 4 = 28$$

- Identify the mass and convert the mass into grams if required.

$$mass(C_2H_4) = 1.4 \text{ kg} = 1400 \text{ g}$$

- Substitute the mass and relative atomic mass (Ar) or Mr into the equation.

$$\boldsymbol{mol(C_2H_4)} = \frac{mass(C_2H_4)}{Mr(C_2H_4)} = \frac{1400}{28} = 50 \text{ mol}$$

Sometimes we need to deduce the mass from information in the question.

For example: How many moles of gold are there in a 9 g wedding ring which is 60% pure gold by mass?

$$\boldsymbol{mol(Au)} = \frac{mass(Au)}{Ar(Au)}$$

- Identify Ar (as gold is an element) using the periodic table.

$$Ar(Au) = 197$$

- Identify the mass and convert the mass into grams if required.

$$mass(Au) = 60\% \text{ of } 9 \text{ g} = \frac{60}{100} \times 9 = 5.4 \text{ g}$$

- Substitute the mass and Ar (or Mr) into the equation.

$$\boldsymbol{mol(Au)} = \frac{mass(Au)}{Ar(Au)} = \frac{5.4}{197} = 0.027 \text{ mol}$$

Practice questions

1. A biologist makes up a solution of trypan blue (an azo dye with a chemical formula $C_{34}H_{24}N_6Na_4O_{14}S_4$) to see cell walls under a microscope. How many moles are there in the 600 mg of trypan blue she uses to make her solution? $Mr(C_{34}H_{24}N_6Na_4O_{14}S_4) = 960$
2. A paracetamol tablet has a mass of 0.7 grams. However, 28.6% of the tablet is castor oil, starch and stearic acid. How many moles of paracetamol ($C_8H_9NO_2$) are in the tablet?

Part 2: Working out the mass given the number of moles of a known substance

Worked example

What is the mass of 3 moles of carbon monoxide?

$$mol(CO) = \frac{mass(CO)}{Mr(CO)}$$

- Identify Mr using the periodic table.

$$Mr(CO) = 12 + 16 = 28$$

- Substitute the number of moles and Mr into the equation.

$$3 = \frac{mass(CO)}{28}$$

- Rearrange the equation to make mass the subject.
- Multiply both sides by 28.

$$3 \times 28 = \frac{mass(CO)}{28} \times 28$$

- Cancel the two 28s on the top and bottom of the fraction on the right-hand side.

$$mass(CO) = 3 \times 28 = 84 \text{ g}$$

Practice questions

1. A chemistry teacher is planning a demonstration in which they burn magnesium in a jar of oxygen. The jar of oxygen contains 0.200 moles of oxygen gas. Two moles of magnesium react with one mole of oxygen gas.

(a) Write a chemical equation to show the reaction between magnesium and oxygen.
(b) Calculate the mass of magnesium the teacher needs to use, assuming a complete reaction takes place.
(c) Why is the teacher likely to use a greater mass of magnesium than you calculated in (b)?

2. Aspirin ($C_9H_8O_4$) is synthesised from salicylic acid ($C_7H_6O_3$) in a 1:1 ratio.

(a) A synthetic chemist uses 2.0 grams of salicylic acid. How many moles of salicylic acid did they use?
(b) If there is a 50% yield, what is the mass of pure aspirin that the chemist synthesises?
(c) The actual mass of the product is 1.7 g. What is the percentage by mass of aspirin in the impure product?

Part 3: Working out the identity of a substance from a known mass and known number of moles.

Worked example

4.75 g of a gas was found to contain 0.05 moles of an unknown haloalkane (CH_3X). Identify X.

$$mol(CH_3X) = \frac{mass(CH_3X)}{\boldsymbol{Mr(CH_3X)}}$$

- Substitute the mass and number of moles into the equation.

$$0.05 = \frac{4.75}{\boldsymbol{Mr(CH_3X)}}$$

- Rearrange the equation to make Mr the subject.
- Multiply both sides by $Mr(CH_3X)$ and cancel down on the right-hand side.

$$\boldsymbol{Mr(CH_3X)} \times 0.05 = \frac{4.75}{\boldsymbol{Mr(CH_3X)}} \times \boldsymbol{Mr(CH_3X)} = 4.75$$

- Divide both sides by 0.05 and cancel down on the left-hand side.

$$\frac{\boldsymbol{Mr(CH_3X)} \times 0.05}{0.05} = \boldsymbol{Mr(CH_3X)} = \frac{4.75}{0.05} = 95$$

- Work out the identity of the unknown substance.
- We need to calculate Mr of the whole molecule to identify the Ar of X:

$$Mr(CH_3X) = Ar(C) + (3 \times Ar(H)) + \boldsymbol{Ar(X)}$$

$$95 = 12 + (3 \times 1) + \boldsymbol{Ar(X)}$$

$$\boldsymbol{Ar(X)} = 95 - 12 - (3 \times 1) = 80$$

- Use the periodic table to identify which element has an Ar of 80:

$$\boldsymbol{Ar(Br)} = 80 \therefore X = Br$$

Practice questions

1. Benzene (C_6H_6) undergoes a substitution reaction with chlorine (Cl_2), in which chlorine atoms replace one of more of the hydrogen atoms and hydrogen chloride (HCl) is produced. A chemist starts with 4.00 g of benzene and produces 9.31 g of chlorobenzene in a 1:1 ratio.

(a) How many moles of benzene are there at the beginning of the reaction?
(b) Assuming there is a 100% yield of pure chlorobenzene, calculate the Mr of the product.
(c) Determine the chemical formula of the chlorobenzene produced and write a chemical equation to show the overall reaction.

2. An unknown metal (A) is burned in 0.050 mol of oxygen to produce a compound which has a formula of either A_2O or AO and a mass of 5.6 g. Calculate the relative formula mass of the metal oxide and suggest a possible identity for the unknown metal. Show your reasoning.