Checkpoint Task: Amount of Substance

Introduction

This activity will probe your understanding of the words used to describe chemical quantities and amounts, and how they relate to the symbols (balanced equations), calculations and observations that happen in chemical reactions.

Task 1

Read through each of the ten statements below. Decide whether you think each statement is true or false. For each of the statements you will need to justify your true/false answer with an explanation or example. If you have decided that a statement is true, try to give an explanation using the chemical concepts and definitions you know. If you have decided that a statement is false, you could find an example of a chemical process, reaction or balanced equation where it is not the case.

1. The total number and type of atoms present are the same at the start and end of a reaction.

2. The amount of substance, measured in moles, is the same at the start and end of a reaction.

3. The total mass of reactants is equal to the total mass of products for any reaction.

4. The total volume of gas is the same at the start and the end of a reaction.

5. The amount in moles is proportional to the number of particles for that substance.

6. One mole of methane molecules (CH_4) contains 1/5 mole of carbon atoms and 4/5 mole of hydrogen atoms.

7. One mole of methane molecules (CH_4) contains 1 mole of carbon atoms and 4 moles of hydrogen atoms.

8. 100 cm^3 of methane gas contains the same number of molecules as 100 cm^3 hydrogen gas at room temperature and pressure.

9. 100 cm^3 of methane gas at room temperature and pressure has the same mass as 100 cm^3 of hydrogen gas under the same conditions.

10. If 0.1 mol of magnesium atoms reacts with a solution containing 0.1 mol of hydrochloric acid, 0.1 mol of hydrogen molecules will be produced. (Hint – you may need to look up or work out the balanced equation for this reaction.)

True / False statements and explanations:

1. The total number and type of atoms present are the same at the start and end of a reaction.

True. This is of course the basis of balanced equations. Matter cannot be created or destroyed and in chemical reactions atoms retain their identity (proton number) although they may change the number of electrons. It may be worth checking that learners understand the difference between chemical reactions and nuclear reactions, as they will no doubt have come across examples where the element identity does change.

2. The amount of substance, measured in moles, is the same at the start and end of a reaction.

False. Thermal decomposition reactions such as the breakdown of metal carbonates or catalytic cracking are good examples of why this is not the case:

$CaCO_3 \rightarrow CaO + CO_2$

$C_{10}H_{22} \rightarrow 2C_2H_4 + C_6H_{14}$

These are not the only examples, but if a substance breaks down into smaller substances then there will be more moles in the products than in the reactants. Conversely, addition reactions produce one product from two. An everyday analogy such as dismantling a bicycle helps to show why 'amount' is not conserved – from one bicycle you can obtain two wheels, one handlebar, one seat etc.

3. The total mass of reactants is equal to the total mass of products for any reaction.

True. This statement is inextricably linked with the first statement, since the atoms involved do not change their mass during a reaction. Learners may have become confused about mass loss due to reactions where gas is given off (this is a popular way of measuring reaction rate after all) so try getting them to imagine (or indeed demonstrate) what happens if a balloon is put over the end of the reaction vessel and the change in mass monitored.

4. The total volume of gas is the same at the start and the end of a reaction.

False. The two reactions used in statement 2 above also apply to this, since in both the decomposition of carbonates and cracking of liquid hydrocarbons there are no gases in the reactants. Similarly the reaction of acids with metals or metal carbonates provide simple examples.

5. The amount in moles is proportional to the number of particles for that substance.

True. This statement is likely to generate discussion over the meaning of the term 'particles'. When quantifying the amount of substance using the mole as a unit, it is important to be specific about whether you are referring to moles of atoms, moles of molecules, moles of ions or simply moles of a 'repeat unit' for giant structures. Either way this statement remains true due to the phrase 'proportional'. The number of carbon dioxide molecules in a mole is proportional to Avogadro's number; so is the number of oxygen atoms in a mole of carbon dioxide molecules.

6. One mole of methane molecules (CH_4) contains 1/5 mole of carbon atoms and 4/5 mole of hydrogen atoms.

False. The use of molecular modelling kits could be useful in explaining this to learners as it is a surprisingly common misconception. Demonstrate taking apart a model of methane so that learners can see how many atoms are produced; it is important that they are happy with the relationship between amount in moles and number of molecules so that they can see the two quantities follow the same rules. Everyday analogies may also be useful again – taking apart a bicycle does not produce 2/3 wheels and 1/3 frame!

7. One mole of methane molecules (CH_4) contains 1 mole of carbon atoms and 4 moles of hydrogen atoms.

True. Statement 6 and 7 are mutually exclusive and so the same explanation can be applied to both.

8. 100 cm^3 of methane gas contains the same number of molecules as 100 cm^3 hydrogen gas at room temperature and pressure.

True. It is surprising how often learners use the molar gas volume in equations without being fully aware of its implications in terms of the amount of substance. Diagrams which show the relative space between particles compared to the size of particles (the empty space in argon activity can be used for able learners) in a gas can help to explain this, along with the PhET simulation.

9. 100 cm^3 of methane gas at room temperature and pressure has the same mass as 100 cm^3 of hydrogen gas under the same conditions.

False. By calculating the relative formula masses of methane and hydrogen, it can be seen that statements 8 and 9 must be mutually exclusive. Molymods or differing size balls or marbles could be used to demonstrate two containers which contain the same number of particles in a given volume but which have a different total mass.

10. If 0.1 mol of magnesium atoms reacts with a solution containing 0.1 mol of hydrochloric acid, 0.1 mol of hydrogen molecules will be produced. (Hint – you may need to look up or work out the balanced equation for this reaction.)

False. This statement tests learner understanding of 'excess' which is often poorly understood despite being used fairly regularly as a technique for salt preparation or reaction rate measurement. The balanced equation for the reaction is as follows:

$$Mg + 2HCl \rightarrow MgCl_2 + H_2$$

It therefore follows that magnesium reacts with hydrochloric acid in a 2 : 1 ratio; HC*l* is a limiting reagent in this example as only 0.05 mol of magnesium will react with 0.1 mol of acid. Since the equation shows that one mole of magnesium reacts to produce one mole of hydrogen, the total amount of hydrogen produced in this case will be 0.05 mol. This can also be demonstrated using models to show the particles that are used up compared to the particles that are left behind, and again the bicycle analogy can be brought into play – having two frames and two wheels does not mean I can assemble two bicycles!