Chemistry

Key Stage 4
Tutor Guidance

BRILLIANT TUTORING PROGRAMME

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Module 1 - Moles

Tutorial	Topic
Tutorial 1.1	Moles
Tutorial 1.2	Amounts of Substances in Equations
Tutorial 1.3	Percentage Yield and Atom Economy
Tutorial 1.4	Moles and Gas Volumes

Tutorial 1.1 - Moles

In this tutorial you will look at:

- Describing the measurement of amounts of substance in moles
- Calculating number of moles of particles of a substance in a given mass of that substance and vice versa
- Calculating the number of particles of a substance in a given number of moles or mass of that substance and vice versa

Maths skills for this lesson:

- Completing calculations with numbers written in standard form

Knowledge Check 1

At the beginning of this tutorial you will guide pupils through a set of confidence and Knowledge Check questions – you'll find more details about this on the relevant tutorial slides.

Answers:

1. The volume of one mole of any gas at room temperature and pressure is 24.0 dm^3. How many moles of carbon dioxide is 95.0 cm^3?

   A. 3.96×10^{-3} mol ✓
   B. 3.96 mol
   C. 0.253 mol
   D. 253 mol

2. 40 kg of titanium chloride was added to 20 kg of sodium. The equation for the reaction is:
   $TiCl_4 + 4\ Na \rightarrow Ti + 4\ NaCl$
   Relative atomic masses (Ar): Na = 23 Cl = 35.5 Ti = 48
   For a Stage 2 reaction the percentage yield was 92.3%. The theoretical maximum mass of titanium produced in this batch was 13.5 kg. The actual mass of titanium produced was:

   A. 12.5 kg ✓
   B. 12 kg
   C. 13 kg
   D. 13.5 kg

3. A student wanted to make 11.0 g of copper chloride. The equation for the reaction is:
   $CuCO_3 + 2HCl \rightarrow CuCl_2 + H_2O + CO_2$
   Relative atomic masses, Ar: H = 1; C = 12; O = 16; Cl = 35.5; Cu = 63.5
   What is the mass of copper carbonate the student should react with dilute hydrochloric acid to make 11.0 g of copper chloride?

   A. 8.2g
   B. 11g
   C. 9.7g
   D. 8.7 g ✓

Lesson summary:

This first lesson is an introduction to mole calculations where student will apply their maths skills in order to calculate the moles, mass or number of particles of a substance.

Common misconceptions:

- Students not understanding what a mole is and why it's used (it will be good to compare with familiar terms e.g. 'a dozen' represents a specific quantity of 12; 'a pair' represents a specific quantity of 2)
- Students not converting kilograms into grams before calculating moles (see summary question 5)
- Students not quoting values to the correct number of significant figures (see worked example 3)
- Issues with calculating mole ratios of atoms within a compound to the compound itself (see worked example 4)

Assessing students' progress:

LO1: Describing the measurement of amounts of substance in moles

Students will meet LO1 if they can successfully answer summary questions 1-2 and exam question 2

LO2: Calculating the number of moles of particles of a substance in a given mass of that substance and vice versa

Students will meet LO2 if they can successfully answer summary questions 3-6 and exam question 2

LO3: Calculating the number of particles of a substance in a given number of moles or mass of that substance and vice versa

Students will meet LO3 if they can successfully answer summary questions 7-10 and exam question 3

Tutorial Activity Answers:

Starter activity

In chemistry, the term 'one mole' (symbol: mol) is a term used to quantify a specific number of particles in a substance. The number of particles in a substance is often very large and so using the term *mole* makes it much easier to quantify things in chemistry.

Summary Questions

1. One mole of a substance is 6.02×10^{23} of particles of that substance **[1 mark]**

2. 1 mol copper; 1 mol water; 1 mol hydrogen gas **[1 mark]**

3. M_r of C_2H_5OH = 46

Mol = 9.2 g /46 = <u>0.20 mol</u> **[1 mark]**

4. M_r of hydrogen molecule (H_2) = 2

Mol = 4 g /2 = <u>2 mol</u> **[1 mark]**

5. M_r of $Al(OH)_3$ = 78

Mass = 0.039kg x1000 = 39 g

Mol = 39 g /78 = 0.50 mol **[1 mark]**

6. M_r of $(NH_4)_2SO_4$ = 132

Mass = mol x M_r = 0.002 x 132 = 0.264 g ÷ 1000 = 2.64×10^{-4} kg **[1 mark]**

7. M_r of carbon monoxide (CO) = 28

Mol = 0.014 g /28 = 5×10^{-4} mol

Number of molecules = 5×10^{-4} mol x 6.02×10^{23} mol^{-1} = 3.01×10^{20} **[1 mark]**

8. M_r of chlorine gas (Cl_2) = 71

Mol = 0.335 g /71 = 4.72×10^{-3} mol

Number of molecules = 4.72×10^{-3} mol x 6.02×10^{23} mol^{-1} = 2.84×10^{21} **[1 mark]**

9. Mole ratio of $CuSO_4$ to Cu^{2+} ions is 1:1

Therefore moles of Cu^{2+} ions in $CuSO_4$ = 10 mol

Number of copper ions = 10 mol x 6.02×10^{23} mol^{-1} = 6.02×10^{24} **[1 mark]**

10. Mole ratio of $CuCl_2$ to Cl^- ions is 1:2

Therefore moles of Cl^- ions in $CuCl_2$ = 5 x 2 =10 mol

Number of chloride ions = (5x2 mol) x 6.02×10^{23} mol^{-1}

= 6.02×10^{24} **[1 mark]**

TOTAL = 10

Exam-Style Questions

1. M_r of CO_2 = 44 **[1 mark]**

Moles = 6.60 g /44 = 0.15 mol **[1 mark]**

2 marks awarded for correct answer (with or without working out)

2. a) The number of particles per mole of a substance **[1 mark]**

b) 72 g of water = 72 g /18 = 4 moles **[1 mark]**

number of molecules of water = 2.408×10^{24} **[1 mark]**

answer to 3 sig figs = 2.41×10^{24} **[1 mark]**

2 marks awarded for correct answer (with or without working out)

TOTAL = 6

Tutorial 1.2 - Amounts of Substances in Equations

In this tutorial you will look at:

- Calculating masses of reactants or products from balanced equations, given the mass of one substance
- Explaining why, in a reaction, the mass of product formed is controlled by the mass of the reactant which is not in excess
- Deducing the stoichiometry of an equation from the masses of reactants and products

Maths skills for this lesson:

- Using arithmetic computation and ratio when determining empirical formulae, balancing equations
- Changing the subject of a mathematical equation

Lesson summary:

Lesson 2 focuses on applying mole calculations that were taught in session 1 to chemical reactions and their balanced equations. Students are introduced to this session with a starter activity, which explores why equations need to be balanced.

Common misconceptions:

- Students include the coefficients from balanced equations as part of their mole calculations.

e.g. For summary question 2, students may incorrectly work out the moles of Fe as:

Moles of Fe = mass/A_r

= 28.0 g / 2 x 56

= 0.25 mol

instead of:

Moles of Fe = mass/A_r

= 28.0 g / 56

= 0.50 mol

Students should be made aware that coefficients are only used to work out the mole ratios of species in an equation.

- Students mistake the coefficients in a balanced equation as the theoretical moles of a reactant or product.

e.g. For <u>summary question</u> 2, students may incorrectly deduce the theoretical mole of Fe as 2 moles (as shown in the balanced equation). Therefore, students will avoid correctly calculating the moles of Fe instead using the mole equation (mass/A_r)

Assessing students' progress:

LO1: Calculating masses of reactants or products from balanced equations, given the mass of one substance

Students will meet LO1 if they can successfully answer summary questions 3 and exam questions 1 (ii) and 2(ii)

LO2: Explaining why, in a reaction, the mass of product formed is controlled by the mass of the reactant, which is not in excess

Students will meet LO2 if they can successfully answer summary questions 2 and exam question 1 (ii) and 2 (i)

LO3: Deducing the stoichiometry of an equation from the masses of reactants and products

Students will meet LO3 if they can successfully answer summary questions 4 and exam question 3

Tutorial Activity Answers:

Starter Activity

1. **3** Cl_2 + **6** NaOH → **5** NaCl + $NaClO_3$ + $3H_2O$

Working out:

Cl = ~~2~~ **6**	Cl = ~~2~~ **6**
Na = ~~1~~ **6**	Na = ~~2~~ **6**
O = ~~1~~ **6**	O = **6**
H = ~~1~~ **6**	H = **6**

2. $3\ N_2O_4 + 2\ H_2O \rightarrow 4\ HNO_3 + 2\ NO$

Working out:

N = ~~2~~ **6**	N = ~~3~~ **6**
H = ~~2~~ **4**	H = ~~1~~ **4**
O = ~~5~~ **14**	O = ~~5~~ **14**

Summary Questions

1. $2C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O$

2 mol : 16 mol

Simplified 1 mol : 8 mol

Therefore 1 mole of octane will produce 8 moles of carbon dioxide **[1 mark]**

2. Moles of Fe = mass/A_r

= 28.0 g / 56

= 0.50 mol

Mole ratio of Fe: $FeCl_3$ is 1:1

Therefore 0.50 mol of $FeCl_3$ is produced

Maximum mass of $FeCl_3$ produced = mol x M_r

= 0.50 mol x 162.5

= **81.25 g** **[1 mark]**

3. Moles of Al_2O_3 = mass/M_r

= 204g/102

= 2 mol

Mole ratio of Al to Al_2O_3 is 2:1

Therefore, moles of Al used up = 2 mols x 2 = 4 mols

Mass of Al = mol x A_r

= 4 x 27

= 108 g **[1 mark]**

4. ....N_2 (g) + ...H_2 (g) → .... NH_3 (g)

84g/28 : 18g/2 : 102g/17 **[1 mark]**

3 mol/3 : 9 mol/3 : 6 mol/3

1 mol : 3 mol : 2 mol

Therefore, the balanced symbol equation is:

N_2 (g) + **3**H_2 (g) → **2** NH_3 (g) **[1 mark]**

TOTAL = 5

Exam-Style Questions

1. a) Mg (s) + H_2O (g) → MgO (s) + H_2 (g)

[1 mark for correct formula for all species; 1 mark for correct state symbols]

b) Moles of Mg = 2.00g/24

= 0.0833 mol **[1 mark]**

Mole ratio of Mg to MgO is 1:1.

Therefore, moles of MgO = 0.0833 mol

Maximum mass of MgO = mol x M_r

= 0.083 mol x 40 **[1 mark- ecf for incorrect mol of Mg]**

= 3.33 g **[1 mark-ecf]**

3 marks awarded for correct answer to 3.s.f (with or without working out)

2. a) M_r of $C_6H_8O_7$ = 192

Moles of $C_6H_8O_7$ = mass/ M_r

= 20.0 g/192

= 0.104 mol **[1 mark]**

Mole ratio of $C_6H_8O_7$ to $NaHCO_3$ is 1:3

Therefore moles of $NaHCO_3$ = 0.104 x 3

= 0.312 mol **[1 mark-ecf for incorrect mols]**

Minimum mass of $NaHCO_3$ = mol x M_r

= 0.312 mol x 84 **[1 mark]**

= <u>26.2 g</u> **[1 mark]**

4 marks awarded for correct answer to 3.s.f (with or without working out)

b) Moles of H_2O = 7.2 g/18

=0.400 mol **[1 mark]**

Mole ratio of H_2O to $C_6H_8O_7$ is 3:1

Moles of $C_6H_8O_7$ used up = 0.400mol/ 3

= 0.133 mol **[1 mark –ecf for incorrect mole of H_2O]**

Mass of $C_6H_8O_7$ reacted = mol x M_r

= 0.133 mol x 192 **[1 mark]**

= 25.5 g **[1 mark]**

4 marks awarded for correct answer to 3.s.f (with or without working out)

3. a) Mass of oxygen used up 17.65g -14.10g = 3.55 g **[1 mark]**

	………A +	……O_2 →	…….AO_x
mass	14.10 g	3.55 g	17.65 g
Moles		3.55 g/32	17.65g/79.5
		0.1109 mol	0.2222 mol **[1 mark each for correct moles]**
		0.1109/0.1109	0.2222/0.110 **[1 mark for division by smallest mole]**
		1mol	2 mol

Moles of Metal A in balanced equation must be 2 mol **[1 mark]**

<u>OR</u>

2A + O_2 → 2AO_x

M_r of A = mass/moles

= 14.10g/ 0.2222 mol

= 63.5

The actual number of moles of Cu must be used instead

Metal A = Cu **[1 mark]**

AO_x = CuO **[1 mark]** (x must be 1 to maintain a balanced equation)

b) $2Cu\ (s) + O_2\ (g) \rightarrow 2CuO\ (s)$

[1 mark for correct formula for all species; 1 mark for correct state symbols]

TOTAL = 21

Tutorial 1.3 - Percentage Yield and Atom Economy

In this tutorial you will look at:

- Calculating the percentage yield of a reaction from the actual yield and the theoretical yield
- Explaining why the actual yield of a reaction is usually less than the theoretical yield
- Calculating the atom economy of a reaction to form a desired product from the balanced equation
- Explaining why a particular reaction pathway is chosen to produce a specified product given appropriate data

Maths skills for this lesson:

- Completing arithmetic computation when calculating yields and atom economy

Lesson summary:

In lesson 3 students will learn how to calculate percentage yield. Students will also learn why percentage yields are often less than 100%. In addition, students will learn how to calculate percentage atom economy and use their understanding of this calculation to evaluate the reaction method that should be used for mass production.

Common misconceptions:

- Students must remember to include the coefficients of balanced equations when working out the M_r of desired products and total reactants. This is only applicable for percentage atom economy calculations
- Students must remember that theoretical yields are always greater than actual yields
- Theoretical yields are always in the denominator of the percentage yield equation and actual yields in the numerator of the equation
- Errors often arise when students calculate M_r. Students should be encouraged to check their Mr calculations twice to avoid making unnecessary mistakes)

Assessing students' progress:

LO1: Calculating the percentage yield of a reaction from the actual yield and the theoretical yield

Students will meet LO1 if they can successfully answer summary questions 1 and exam questions 1 (i)

LO2: Explaining why the actual yield of a reaction is usually less than the theoretical yield

Students will meet LO2 if they can successfully answer summary questions 2 and exam question 1 (iii)

LO3: Calculating the atom economy of a reaction to form a desired product from the balanced equation

Students will meet LO3 if they can successfully answer summary questions 3 and exam question 1 ii)

LO4: Explaining why a particular reaction pathway is chosen to produce a specified product given appropriate data

Students will meet LO4 if they can successfully answer summary questions 4 and exam question 2

Tutorial Activity Answers:

Starter Activity

1. The term 'yield' relates to the amount of product you obtain which it often measured in grams (but it can also be other units such as tonnes)

2. If a reaction has 100% percentage yield, this means that the actual mass or moles of the product obtained is equal to the theoretical mass or moles of the product. This means that you have obtained all the product you expected to get!

3. We need to know two things before we can determine the percentage yield of a reaction:

- Theoretical Yield
- Actual Yield

Summary Questions

1) Moles of KI = mass/ M_r

= 3.32g / 166

= 0.0200 mol **[1 mark]**

Mole ratio of KI : PbI_2 is 2:1

Therefore, the theoretical moles of PbI_2 produced is 0.0200 /2 = 0.0100 mol **[1 mark]**

Maximum theoretical mass of PbI_2 = mol x M_r

= 0.0100 mol x 461

= 4.61 g of PbI_2

Percentage Yield = $\frac{\text{Actual Yield}}{\text{Theoretical Yield}}$ x 100

$= \frac{3.92 \text{ g}}{4.61 \text{ g}}$ x 100

= 85 % **[1 mark]**

2)

- Some of the product may be lost when it is separated from the reaction mixture e.g. lost during filtration **[1 mark]**
- Some of the reactants may react in ways different to the expected reaction i.e. Unexpected side reactions may occur **[1 mark]**

3) M_r of desired product (2 Cu) = 2 x 63.5

= 127 **[1 mark]**

M_r of all reactants (2 CuO + C) = (2 x 63.5) + (2 x 16) + 12

= 171

Percentage Atom Economy = $\frac{127}{171}$ x100

= 74.3% **[1 mark]**

4) Method 1:

Percentage Atom Economy = $\frac{32}{68.5}$ x100

= 46.7% **[1 mark]**

Method 2:

Percentage Atom Economy = $\frac{32}{68}$ x100

= 47.0% **[1 mark]**

Very close percentage atom economies! but method 2 should be selected, as it's percentage atom economy is slightly higher **[1 mark]**

TOTAL = 10

Exam-Style Questions

1\. a) Moles of $CaCO_3$ = mass/ M_r

= 24.00 g / 100 **[1 mark for M_r]**

= 0.24 mol **[1 mark]**

Mole ratio of $CaCO_3$: CaO is 1:1

Therefore the theoretical moles of CaO produced is 0.24 mol **[1 mark- ecf for incorrect mole of $CaCO_3$]**

Maximum theoretical mass of CaO = mol x M_r

= 0.24 mol x 56

= 13.44 g **[1 mark –ecf]**

Percentage Yield = $\frac{\text{Actual yield}}{\text{Theoretical yield}} \times 100$

= $\frac{4.75\ g}{13.44\ g} \times 100$ **[1 mark ecf]**

= 35.3 % **[1 mark ecf]**

b) M_r of desired product ($CaSO_4$) = 40 + 32 + (16 x 4)

= 136 **[1 mark]**

M_r of all reactants ($CaO + H_2SO_4$) = (40 +16) + (2 + 32 + (16 x 4))

=154 **[1 mark]**

Percentage Atom Economy = $\frac{136}{154} \times 100$

= 88.3% **[1 mark]**

c) The student is incorrect **[1 mark]**

More reaction steps means more chances to lose product at each stage **[1 mark]**

2. a) Method 1:

Percentage Atom Economy $= \frac{240}{276} \times 100$

$= 87.0\%$ **[1 mark]**

Method 2:

Percentage Atom Economy $= \frac{58}{120} \times 100$

$= 48.3\%$ **[1 mark]**

The **oxidation of butane** should be selected as it has a higher percentage atom economy; therefore less waste is produced via this process **[1 mark]**

b) Use a catalyst so that lower temperatures can be used/ no need to heat reaction mixture **[1 mark]**

TOTAL = 15

Tutorial 1.4 - Moles and Gas Volumes

In this tutorial you will look at:

- Describing the relationship between molar amounts of gases and their volumes and vice versa
- Calculating the volumes of gases involved in reactions using the molar gas volume at room temperature and pressure
- Calculating volumes of gases from a balanced equation and a given volume or mass of a reactant or product

Maths skills for this lesson:

- Converting units where appropriate particularly from mass to moles
- Completing arithmetic computation, ratio, percentage and multistep calculations permeates quantitative chemistry
- Providing answers to an appropriate number of significant figures

Lesson summary:

In lesson 4 students will learn the relationship between moles and molar gas volume through Avogadro's Gas Law. As a result, students will be able to apply the mathematical skills and theory they learnt in session 2 (amounts of substances and equations) to work out the moles, volume or mass of reactants and products from balanced symbol equations

Common misconceptions:

- Students often incorrectly divide the volume by the wrong value when calculating the moles using Avogadro's Law. Students must remember a volume of dm^3 provided in the question means you must divide by 24 and a volume of cm^3 provided in the question means you must divide by 24000
- Students must remember how to convert from dm^3 to cm^3 and vice versa

Assessing students' progress:

LO1: Describing the relationship between molar amounts of gases and their volumes and vice versa

Students will meet LO1 if they can successfully answer the starter activity and exam questions 3

LO2: Calculating the volumes of gases involved in reactions using the molar gas volume at room temperature and pressure

Students will meet LO2 if they can successfully answer summary questions 1-2 and exam question 2 (i)

LO3: Calculating volumes of gases from a balanced equation and a given volume or mass of a reactant or product

Students will meet LO3 if they can successfully answer summary questions 3-5 and exam question 1 , 2 (ii) and 4

Tutorial Activity Answers:

Starter Activity

a) Sally incorrect.

This is because all three gases have different relative molecular/atomic masses (H_2 = 2; Ne= 20 and SO_2 = 64).

As a result, the container of SO_2 gas would weigh the most

b) Jill is correct

Avogadro's Law states that when the temperature and pressure stay the same: equal volumes of different gases contain an equal number of molecules/moles

Summary Questions

1. a) 2.8 g of nitrogen (N_2)

moles of nitrogen = 2.8 g / 28 =0.1 mol

Volume of nitrogen = 0.1 mol x 24 = 2.4 dm^3 **[1 mark]**

b) moles of oxygen = 64 g / 32 = 2 mol

volume of oxygen = 2 mol x 24 = 48 dm^3 **[1 mark]**

c) moles of methane = 1.6 g /16 = 0.1 mol

volume of methane = 0.1 mol x 24 = 2.4 dm^3 **[1 mark]**

2. a) Volume (dm^3) = number of moles of gas x 24

= 2.0 mol x 24

= 48 dm^3 **[1 mark]**

b) Volume (dm^3) = number of moles of gas x 24

= 0.1 mol x 24

= 2.4 dm^3 **[1 mark]**

c) Volume (dm^3) = number of moles of gas x 24

= 10 mol x 24

= 240 dm^3 **[1 mark]**

3) Volume ratio of NO: CO is 1:1

Therefore 48 dm^3 of NO reacts **[1 mark]**

4) Moles of $CaCO_3$ = mass/M_r

= 1.0 g / 100

= 0.01 mol **[1 mark]**

Mole ratio of $CaCO_3$: CO_2 is 1:1

Therefore 0.01 mol of CO_2 is produced

Volume (cm^3) = number of moles of gas x 24000

= 0.01 x 24000

= 240 cm^3 **[1 mark]**

5) Number of moles of CO_2 = $\frac{12}{24}$ = 0.5 mol **[1 mark]**

Mole ratio of CO_2 : LiOH is 1:2

Therefore 1 mol of LiOH must be absorbed

Mass = mol x M_r

= 1 x 24

= 24 g **[1 mark]**

TOTAL = 11

Exam-Style Questions

1. Moles of $CaCO_3$ = mass/M_r

= 0.400 g / 100

= 4.00×10^{-3} mol **[1 mark]**

Mole ratio of $CaCO_3$: CO_2 is 1:1

Therefore 4.00×10^{-3} mol of CO_2 is produced

Volume (dm^3) = number of moles of gas x 24

= 4.00×10^{-3} x 24 **[1 mark- ecf for incorrect mol of $CaCO_3$]**

= <u>0.096 dm^3</u> **[1 mark –ecf]**

2. a) Number of moles of O_2 = $\frac{60}{24000}$ OR $\frac{0.06}{24}$

= 2.5×10^{-3} mol **[1 mark]**

b) Moles of H_2O_2 = mass/M_r

= 48 g / 34

= 1.4 mol **[1 mark]**

Mole ratio of H_2O_2: O_2 is 2:1

Therefore 0.7 mol of O_2 is produced

Volume = number of moles of gas x 24

= 0.7 x 24 **[1 mark- ecf for incorrect mol of H_2O_2]**

= <u>16.8 dm^3</u> **[1 mark –ecf]**

<u>OR</u>

Volume = number of moles of gas x 24000

= 0.7 x 24000

= <u>16800 cm</u>

3. Avogadro's Law **[1 mark]** states that at any particular temperature and pressure **[1 mark]** equal volumes of different gases contain an equal number of molecules **[1 mark]**

4. Volume of ammonia produced = 2/3 x 795 **[1 mark]**

= 530 dm^3 **[1 mark]**

530 x 1000 = <u>530000 cm^3</u> **[1 mark]**

TOTAL = 14

Knowledge Check 2

At the end of this tutorial you will guide pupils through a set of confidence and Knowledge Check questions. You will also complete a reflection exercise so that pupils can take time to think about what they found challenging and where they did well – you'll find more details about this on the relevant tutorial slides.

Answers:

1. In industry, methanol is produced by reacting carbon monoxide with hydrogen. The equation for the reaction is:
   $CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g$
   How many moles of carbon monoxide react completely with 4.0×10^3 moles of hydrogen?

   A. 1.0×10^3 mole
   B. 2.0×10^3 moles ✓
   C. 4.0×10^3 moles
   D. 8.0×10^3 moles

2. The equation for the complete combustion of ethane is
   $2C_2H_6\ (g) + 7O2\ (g) \rightarrow 4CO_2\ (g) + 6H_2O(l)$
   Which is the correct volumes of ethane and oxygen that react together and the volume of carbon dioxide they produce when they react as shown in this equation? (all volumes of gases are measured under the same conditions of temperature and pressure)

   A. Ethane: 5, Oxygen: 35, Carbon dioxide: 10
   B. Ethane: 5, Oxygen: 70, Carbon dioxide: 20
   C. Ethane: 10, Oxygen: 35, Carbon dioxide:20 ✓
   D. Ethane: 10, Oxygen: 70, Carbon dioxide:40

3. Look at the equations for the two reactions:
   Reaction 1: $CuCO_3(s) + 2HCl(aq) \rightarrow CuCl_2(aq) + H_2O(l) + CO_2(g)$
   Reaction 2: $CuO(s) + 2HCl(aq) \rightarrow CuCl_2(aq) + H_2O(l)$
   What is the percentage atom economy for Reaction 2?
   A. 89.20%
   B. 85.20%
   C. 88.20% ✓
   D. 87.20%

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