Moles of Ions Calculations

1. 5 moles of ammonium phosphate, $(NH_4)_3PO_4$, contains how many moles of positive ions?

A 3
B 5
C 12
D 15

2 A mixture of sodium bromide and sodium sulfate is known to contain 10 moles of sodium and 4 moles of bromide ions.

How many moles of sulfate ions are present?

A 3
B 4
C 5
D 6

3 The number of moles of positive ions in 0.25 moles of aluminium sulfate is

A 0.5
B 1.0
C 2.0
D 3.0

4 The number of moles of ions in 1 mol of copper(II) phosphate is

A 1
B 2
C 3
D 5.

5 A mixture of magnesium bromide and magnesium sulfate is known to contain 3 moles of magnesium ions and 4 moles of bromide ions.

How many moles of sulfate ions are present?

A 1
B 2
C 3
D 4

6 A mixture of potassium chloride and potassium carbonate is known to contain 0·1 mol of chloride ions and 0·1 mol of carbonate ions.

How many moles of potassium ions are present?

A 0·15
B 0·20
C 0·25
D 0·30

7 **A mixture of sodium chloride and sodium sulphate is known to contain 0·6 mol of chloride ions and 0·2 mol of sulphate ions.**

How many moles of sodium ions are present?

A 0·4
B 0·5
C 0·8
D 1·0

Excess, Percentage Yield & Atom Economy

8. 4·6 g of sodium is added to 4·8 litres of oxygen to form sodium oxide.

When the reaction is complete, which of the following statements will be true?

(Take the volume of 1 mole of oxygen to be 24 litres.)

A 0·10 mol of oxygen will be left unreacted.

B 0·10 mol of sodium will be left unreacted.

C 0·15 mol of oxygen will be left unreacted.

D 0·20 mol of sodium oxide will be formed.

9. $CaCO_3(s) + 2HNO_3(aq) \rightarrow Ca(NO_3)_2(aq) + CO_2(g) + H_2O(\ell)$

Mass of 1 mol = 100 g

Mass of 1 mol = 164 g

2·00 g of calcium carbonate ($CaCO_3$) was reacted with 200 cm^3 of 0·1 mol l^{-1} nitric acid (HNO_3).

Take the volume of 1 mole of carbon dioxide to be 24 litres.

In the reaction

A $CaCO_3$ is the limiting reactant

B an excess of 0·1 mol of nitric acid remains at the end of the reaction

C 1·64 g of calcium nitrate is produced by the reaction

D 480 cm^3 of carbon dioxide is produced by the reaction.

10 A two-step reaction is shown below.

$$A \xrightarrow[\text{step 1}]{} B \xrightarrow[\text{step 2}]{} C$$

The first step gave a yield of 60% and the second step a yield of 90%.

The overall yield would be

A 30%

B 54%

C 67%

D 150%.

11. $CH_3COOH + C_2H_5OH \rightleftharpoons CH_3COOC_2H_5 + H_2O$

Which of the following mixtures would produce 0·8 moles of ester if the yield was 80%?

	moles of CH_3COOH	moles of C_2H_5OH
A	0·4	0·4
B	0·5	0·5
C	0·8	0·8
D	1·0	1·0

12. $TiCl_4 + 2Mg \rightarrow 2MgCl_2 + Ti$

mass of one mole = 189·9 g

mass of one mole = 24·3 g

mass of one mole = 95·3 g

mass of one mole = 47·9 g

The atom economy for the production of titanium in the above equation is equal to

A $\frac{47·9}{189·9+24·3}\times 100$

B $\frac{47·9}{189·9+(2\times 24·3)}\times 100$

C $\frac{95·3+47·9}{189·9+24·3}\times 100$

D $\frac{(2\times 47·9)}{189·9+24·3}\times 100$

13. Iron can be produced from iron(III) oxide.

$2Fe_2O_3(s) + 3C(s) \rightarrow 4Fe(s) + 3CO_2(g)$

GFM = 159·6 g GFM = 12·0 g GFM = 55·8 g GFM = 44·0 g

The atom economy for the production of iron is

A 69·9%

B 62·8%

C 58·2%

D 32·5%.

Excess, Percentage Yield & Atom Economy

14 Magnesium carbonate reacts with nitric acid.

$MgCO_3(s) + 2HNO_3(aq) \rightarrow Mg(NO_3)_2(aq) + H_2O(\ell) + CO_2(g)$

0·05 mol of magnesium carbonate was added to a solution containing 0·06 mol of nitric acid.

Which of the following statements is true?

A 0·05 mol of carbon dioxide is produced

B 0·06 mol of magnesium nitrate is produced

C Magnesium carbonate is in excess by 0·02 mol

D Nitric acid is in excess by 0·01 mol

15 A student obtained a certain volume of carbon dioxide by the reaction of 20 cm^3 of 2 mol l^{-1} hydrochloric acid, HCl, with excess sodium carbonate.

$2HCl(aq) + Na_2CO_3(aq) \rightarrow 2NaCl(aq) + CO_2(g) + H_2O(\ell)$

The student carried out a similar experiment using sulfuric acid, H_2SO_4.

$H_2SO_4(aq) + Na_2CO_3(aq) \rightarrow Na_2SO_4(aq) + CO_2(g) + H_2O(\ell)$

Which solution of sulfuric acid would give the same final volume of carbon dioxide when added to excess sodium carbonate?

A 10 cm^3 of 2 mol l^{-1}

B 20 cm^3 of 2 mol l^{-1}

C 10 cm^3 of 4 mol l^{-1}

D 20 cm^3 of 4 mol l^{-1}

16 Ammonia is manufactured from hydrogen and nitrogen by the Haber Process.

$3H_2(g) + N_2(g) \rightleftharpoons 2NH_3(g)$

If 80 kg of ammonia is produced from 60 kg of hydrogen, what is the percentage yield?

A $\frac{80}{340} \times 100$

B $\frac{80}{170} \times 100$

C $\frac{30}{80} \times 100$

D $\frac{60}{80} \times 100$

17 20 cm^3 of ammonia gas reacted with an excess of heated copper(II) oxide.

$3CuO + 2NH_3 \rightarrow 3Cu + 3H_2O + N_2$

Assuming all measurements were made at 200 °C, what would be the volume of gaseous products?

A 10 cm^3

B 20 cm^3

C 30 cm^3

D 40 cm^3

Excess, Percentage Yield & Atom Economy

18 100 cm^3 of propane is mixed with 600 cm^3 of oxygen and the mixture is ignited.

$$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(\ell)$$

At the end of the reaction, the total volume of gas would be

A 300 cm^3

B 400 cm^3

C 700 cm^3

D 800 cm^3.

19 20 cm^3 of butane is burned in 150 cm^3 of oxygen.

$C_4H_{10}(g) + 6\frac{1}{2}O_2(g) \rightarrow 4CO_2(g) + 5H_2O(g)$

What is the total volume of gas present after complete combustion of the butane?

A 80 cm^3

B 100 cm^3

C 180 cm^3

D 200 cm^3

20 $2NO(g) + O_2(g) \rightarrow 2NO_2(g)$

How many litres of nitrogen dioxide gas could theoretically be obtained in the reaction of 1 litre of nitrogen monoxide gas with 2 litres of oxygen gas?

(All volumes are measured under the same conditions of temperature and pressure.)

A 1

B 2

C 3

D 4

21 $2C_2H_2(g) + 5O_2(g) \longrightarrow 4CO_2(g) + 2H_2O(\ell)$

ethyne

What volume of gas would be produced by the complete combustion of 100 cm^3 of ethyne gas?

All volumes were measured at atmospheric pressure and room temperature.

A 200 cm^3

B 300 cm^3

C 400 cm^3

D 800 cm^3

22 A pupil added 0·1 mol of zinc to a solution containing 0·05 mol of silver(I) nitrate.

$Zn(s) + 2AgNO_3(aq) \rightarrow Zn(NO_3)_2(aq) + 2Ag(s)$

Which of the following statements about the experiment is correct?

A 0·05 mol of zinc reacts.

B 0·05 mol of silver is displaced.

C Silver nitrate is in excess.

D All of the zinc reacts.

23 Calcium carbonate reacts with nitric acid as follows.

$CaCO_3(s) + 2HNO_3(aq) \rightarrow Ca(NO_3)_2(aq) + H_2O(\ell) + CO_2(g)$

0·05 mol of calcium carbonate was added to a solution containing 0·08 mol of nitric acid.

Which of the following statements is true?

A 0·05 mol of carbon dioxide is produced.

B 0·08 mol of calcium nitrate is produced.

C Calcium carbonate is in excess by 0·01 mol.

D Nitric acid is in excess by 0·03 mol.

Excess, Percentage Yield & Atom Economy

24 . How many moles of magnesium will react with 20 cm^3 of 2 mol l^{-1} hydrochloric acid?

$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$

A 0·01

B 0·02

C 0·04

D 0·20

25 $3CuO + 2NH_3 \rightarrow 3Cu + N_2 + 3H_2O$

What volume of gas, in cm^3, would be obtained by reaction between 100 cm^3 of ammonia gas and excess copper(II) oxide?

(All volumes are measured at atmospheric pressure and 20 °C.)

A 50

B 100

C 200

D 400

26 $C_2H_6(g) + 3\frac{1}{2}O_2(g) \rightarrow 2CO_2(g) + 3H_2O(\ell)$

When 20 cm^3 of ethane was sparked with 100 cm^3 of oxygen, what was the final volume of gases?

All volumes were measured at atmospheric pressure and room temperature.

A 40 cm^3

B 70 cm^3

C 100 cm^3

D 130 cm^3

27 An experiment involves reacting 0.02 moles of silver ions with ions of a group 7 element to form 2.868 g of precipitate.

Which of the following is the precipitate?

A Silver(I) fluoride

B Silver(I) chloride

C Silver(I) bromide

D Silver(I) iodide

Excess Calculations

1 A preservative added to some fizzy drinks is made by reacting sorbic acid and potassium hydroxide.

In an experiment, 7 g of sorbic acid, $C_6H_8O_2$, is reacted with 250 cm^3 of potassium hydroxide solution, concentration 0.5 mol l^{-1}.

$$C_6H_8O_2(s) + KOH(aq) \rightarrow H_2O(\ell) + C_6H_7O_2K(aq)$$

$GFM = 112$ g

Show, by calculation, that sorbic acid is the limiting reactant.

2 In a reaction, 1900 kg of titanium chloride was reacted with 750 kg of magnesium. Magnesium was the reactant in excess.

Calculate the number of moles of magnesium left unreacted.

3 Nitrogen can react with lithium at room temperature to form the compound lithium nitride, Li_3N.

(i) A scientist prepared a sample of lithium nitride by reacting 0·9 litres of nitrogen gas with 0·5 g of lithium.

$$6Li(s) + N_2(g) \rightarrow 2Li_3N(s)$$

$GFM = 6{\cdot}9$ g

2 Determine, by calculation, which of the reactants was in excess. **3**

Take the volume of 1 mole of nitrogen gas to be 24 litres.

(Clearly show your working for the calculation.)

4 A student prepared a sample of methyl cinnamate from cinnamic acid and methanol.

3

cinnamic acid	+	methanol	→	methyl cinnamate	+	water
mass of one mole = 148 g		mass of one mole = 32 g		mass of one mole = 162 g		

6·5 g of cinnamic acid was reacted with 2·0 g of methanol.

Percentage Yield

5 Phosphorus can be obtained by reacting calcium phosphate with silicon dioxide and carbon.

$$2Ca_3(PO_4)_2 + 6SiO_2 + 10C \rightarrow 6CaSiO_3 + 10CO + P_4$$

$GFM = 310.3$ g $\qquad$ $GFM = 124.0$ g

(i) 750 g of calcium phosphate, $Ca_3(PO_4)_2$, produced 115.5 g of phosphorus.

Calculate the percentage yield of phosphorus, P_4. **2**

6 One method of preparing silicon hydride involves reacting magnesium silicide, Mg_2Si, with hydrochloric acid, HCl.

15.32 g of magnesium silicide was reacted with excess hydrochloric acid. 2.56 g of silicon hydride was produced.

$$4HCl + Mg_2Si \rightarrow SiH_4 + 2MgCl_2$$

$GFM = 76.7$ g $\qquad$ $GFM = 32.1$ g

Calculate the percentage yield of silicon hydride. **2**

7 A student prepared a sample of methyl cinnamate from cinnamic acid and methanol.

cinnamic acid	+	methanol	→	methyl cinnamate	+	water
mass of one mole = 148 g		mass of one mole = 32 g		mass of one mole = 162 g		

6·5 g of cinnamic acid was reacted with 2·0 g of methanol.

The student obtained 3·7 g of methyl cinnamate from 6·5 g of cinnamic acid.

Calculate the percentage yield. **2**

8 A scientist prepared a sample of methyl salicylate using 28·3 g salicylic acid and an excess of reactant **X**.

$$C_7H_6O_3 + \mathbf{X} \rightarrow C_8H_8O_3 + H_2O$$

salicylic acid $\qquad$ methyl salicylate

$GFM = 138$ g $\qquad$ $GFM = 152$ g

The scientist produced 24·7 g of methyl salicylate.

Calculate the percentage yield of methyl salicylate. **2**

Percentage Yield

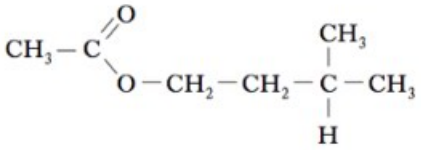
9 The overall equation for the fermentation of glucose is

$$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$$

$C_6H_{12}O_6$		$2C_2H_5OH$		$2CO_2$
mass of one mole = 180 g		mass of one mole = 46 g		

Calculate the percentage yield of ethanol if 445 g of ethanol is produced from 1·0 kg of glucose.

10 One of the chemicals released in a bee sting is an ester that has the structure shown.



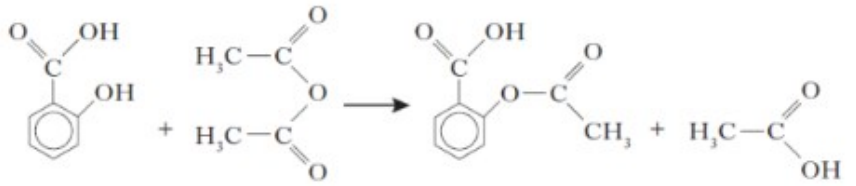
This ester can be produced by the reaction of an alcohol with an alkanoic acid.

If there is a 65% yield, calculate the mass of ester produced, in grams, when 4·0 g of the alcohol reacts with a slight excess of the acid.

(Mass of one mole of the alcohol = 88 g;
mass of one mole of the ester = 130 g)

Show your working clearly.

11 Aspirin, a common pain-killer, can be made by the reaction of salicylic acid with ethanoic anhydride.



$C_7H_6O_3$	$C_4H_6O_3$	$C_9H_8O_4$	$C_2H_4O_2$
salicylic acid	ethanoic anhydride	aspirin	ethanoic acid
mass of one mole = 138 g	mass of one mole = 102 g	mass of one mole = 180 g	mass of one mole = 60 g

In a laboratory preparation of aspirin, 5·02 g of salicylic acid produced 2·62 g of aspirin.

Calculate the percentage yield of aspirin.

12 In the lab, methanamide can be prepared by the reaction of methanoic acid with ammonia.

$$HCOOH + NH_3 \rightleftharpoons HCONH_2 + H_2O$$

HCOOH		NH_3		$HCONH_2$		H_2O
mass of one mole = 46·0 g		mass of one mole = 17·0 g		mass of one mole = 45·0 g		mass of one mole = 18·0 g

When 1·38 g of methanoic acid was reacted with excess ammonia, 0·945 g of methanamide was produced.

Calculate the percentage yield of methanamide.

Percentage Yield

13 Ammonia is produced in industry by the Haber Process.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

Under certain conditions, 500 kg of nitrogen reacts with excess hydrogen to produce 405 kg of ammonia.

Calculate the percentage yield of ammonia under these conditions.

Show your working clearly.

14 Nitrogen and compounds containing nitrogen are widely used in industry.

In the lab, methanamide can be prepared by the reaction of methanoic acid with ammonia.

$$HCOOH + NH_3 \rightleftharpoons HCONH_2 + H_2O$$

methanoic acid — methanamide

When 1·38 g of methanoic acid was reacted with excess ammonia, 0·945 g of methanamide was produced.

Calculate the percentage yield of methanamide.

Show your working clearly.

Atom Economy

15 Methane reacts with steam to produce hydrogen.

$CH_4(g)$	+	$H_2O(g)$	→	$CO(g)$	+	$3H_2(g)$
$GFM = 16$ g		$GFM = 18$ g		$GFM = 28$ g		$GFM = 2$ g

Calculate the atom economy for the formation of hydrogen.

16 The mixture of ethanol and water is made by fermentation followed by distillation.

In fermentation, enzymes in yeast convert glucose, $C_6H_{12}O_6$, into ethanol and carbon dioxide.

The equation for fermentation is shown.

$C_6H_{12}O_6(aq)$	→	$2CH_3CH_2OH(aq)$	+	$2CO_2(g)$
$GFM = 180$ g		$GFM = 46$ g		$GFM = 44$ g

(B) Calculate the atom economy for the production of ethanol. **2**

17 In the second step, titanium chloride reacts with magnesium to produce titanium metal. The reaction is carried out in a sealed vessel, in an argon atmosphere, at 1500 °C.

$TiCl_4$	+	$2Mg$	→	Ti	+	$2MgCl_2$
$GFM = 189.9$ g		$GFM = 24.3$ g		$GFM = 47.9$ g		$GFM = 95.3$ g

(i) Calculate the atom economy for the production of titanium in this reaction. **2**

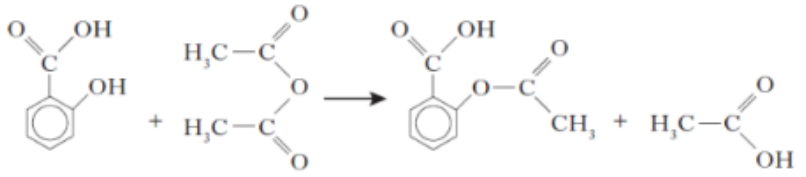
18 Sodium benzoate is used in the food industry as a preservative. It can be made by reacting benzoic acid with a concentrated solution of sodium carbonate.

$2C_6H_5COOH$	+	Na_2CO_3	→	$2C_6H_5COONa$	+	CO_2	+	H_2O
mass of 1 mole = 122 g		mass of 1 mole = 106 g		mass of 1 mole = 144 g		mass of 1 mole = 44 g		mass of 1 mole = 18 g

Calculate the atom economy for the production of sodium benzoate.

Atom Economy

19 Aspirin, a common pain-killer, can be made by the reaction of salicylic acid with ethanoic anhydride.

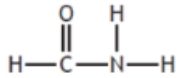


$C_7H_6O_3$	$C_4H_6O_3$	$C_9H_8O_4$	$C_2H_4O_2$
salicylic acid	ethanoic anhydride	aspirin	ethanoic acid
mass of one mole = 138 g	mass of one mole = 102 g	mass of one mole = 180 g	mass of one mole = 60 g

(*a*) Calculate the atom economy for the formation of aspirin using this method.

20 Methanamide, $HCONH_2$, is widely used in industry to make nitrogen compounds.

It is also used as a solvent as it can dissolve ionic compounds.



In industry, methanamide is produced by the reaction of an ester with ammonia.

$HCOOCH_3$	+	NH_3	→	$HCONH_2$	+	CH_3OH
mass of one mole = 60·0 g		mass of one mole = 17·0 g		mass of one mole = 45·0 g		mass of one mole = 32·0 g

(a) Calculate the atom economy for the production of methanamide.

21 Carbon can combine with oxygen to make carbon monoxide, CO.
Carbon monoxide is used in the production of iron from iron(III) oxide.

$Fe_2O_3(s)$	+	$3CO(g)$	→	$2Fe(\ell)$	+	$3CO_2(g)$
$GFM = 159{\cdot}6$ g		$GFM = 28{\cdot}0$ g		$GFM = 55{\cdot}8$ g		$GFM = 44{\cdot}0$ g

Calculate the atom economy for the production of iron. **2**

22

Answers

1. D
2. A
3. A
4. D
5. A
6. D
7 D
8 C
9. C
10. B
11. D
12. B
13. B
14. C
15. A
16. A
17. D
18. B
19. D
20. D
21 A
22 B
23 C
24. D
25. A
26. B
27 B

1.

Correctly calculates number of moles of: Sorbic acid = 0.0625 Potassium hydroxide = 0.125	**2**

2. 10854 (moles of magnesium)

3. stating that nitrogen is in excess or that lithium is the limiting reactant.

Correct calculation of moles of lithium = 0·07/0·072/0·0725 moles **and** nitrogen = 0·04/0·038/0·0375 moles

4.

1 mark awarded for correct arithmetical calculation of moles of acid = 0·044 **and** moles alcohol = 0·063

eg there are less moles of cinnamic acid therefore it is the limiting reactant

5. 77.1%
6. 40%
7. 52%
8. 79.2%
9. 89
10. 3.8g
11. 40%
12. 70%
13. 38%
14. 70%
15 17.65
16 12.2%
17 20.1%
18. 82.3
19. 75%
20. 58.4%
21. 45.8%