Learn Chemistry

# Starter for Ten

## 1. Quantitative Chemistry

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# STARTER FOR 10...

## 1. QUANTITATIVE CHEMISTRY


# STARTER FOR 10...

## 1.1.1. Moles and mass

Work out the answers to the following simple calculations (1 t = 1 tonne = 1,000 kg);

**1.** No. of moles in 10.0 g of $O_2$ + the mass in g of 2.41 moles of $H_2O$ =

(2 marks)

**2.** Mass in g of 0.2 moles of $K_2CO_3$ + mass in g of 0.5 moles of $MgCO_3$ =

(2 marks)

**3.** No. of moles in 12.4 t of $NaNO_3$ ÷ no. of moles in 12.4 t of NaCl =

(2 marks)

**4.** No. of moles in 25.9 g of sodium – no. of moles in 25.9 g of sodium chloride =

(2 marks)

**5.** **?** × molar mass of in g $mol^{-1}$ of calcium carbonate = no. of moles in 4.2 kg of $SiCl_4$

(2 marks)

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## 1.1.2. Mass and concentration

Calculate the answers to the calculations below and place them (to the correct no. of sig. fig.) in the appropriate square. The arrows indicate the direction the numbers must follow. For the 10th mark complete the remainder of the Sudoku grid. (1 mark for each answer)

**WARNING** Take care with your significant figures and RAMs in order to avoid the wrong digit in the wrong square! (Relative atomic masses, H 1.0; 0 16.0; Na 23.0; S 32.1; Cl 35.5; Fe 55.8; Cu 63.5)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| a → | | | 4 | 9 | 8 | 1 | 7 | d ↓ |
| 9 | | c → | b ↓ | 3 | | 8 | 2 | |
| 3 | 1 | 8 | | 2 | e ↓ | | 4 | |
| 7 | 8 | 2 | 6 | | | 9 | | 4 |
| f ↓ | | 4 | g → | | | 2 | 3 | |
| | 3 | 9 | | 4 | | 7 | 8 | |
| | 7 | 6 | 2 | | 1 | 3 | 9 | 8 |
| | | 3 | 9 | h → | | | | 7 |
| | 9 | 1 | 3 | 8 | 7 | i → | | |

(a) The concentration of a solution of 265 moles of NaOH dissolved in 1 $dm^3$ of water (3 sig. fig.)

(b) The volume of water in $dm^3$ needed to dilute 176 moles of HCl to make a 1 mol $dm^{-3}$ solution (3 sig. fig.)

(c) The mass of $H_2SO_4$ that should be dissolved in 1 $dm^3$ of water to make a solution of concentration 0.72 mol $dm^{-3}$ (2 sig. fig.)

(d) The volume of water in $cm^3$ that must be added to 0.56 g of anhydrous $CuSO_4$ to produce a 0.1 mol $dm^{-3}$ solution (2 sig. fig.)

(e) The number of moles of ammonia that must be dissolved in 2,696 $dm^3$ of water to produce 2.0 mol $dm^{-3}$ ammonia solution (4 sig. fig.)

(f) The concentration in mol $dm^{-3}$ of an accurate solution of concentration 16.48537 mol $cm^{-3}$ (5 sig. fig.)

(g) The mass of $FeSO_4.7H_2O$ that must be dissolved in 1,582 $cm^3$ of water to form a solution of concentration 2.0 mol $dm^{-3}$ (to 3 sig. fig.)

(h) The volume in $dm^3$ of water that 10 moles of NaCl must be dissolved in to produce a 0.0155 mol $dm^{-3}$ solution of brine (3 sig. fig.)

(i) The concentration in mol $dm^{-3}$ of a solution of NaOH with a concentration of 18,480 kg $m^{-3}$ (3 sig. fig.)


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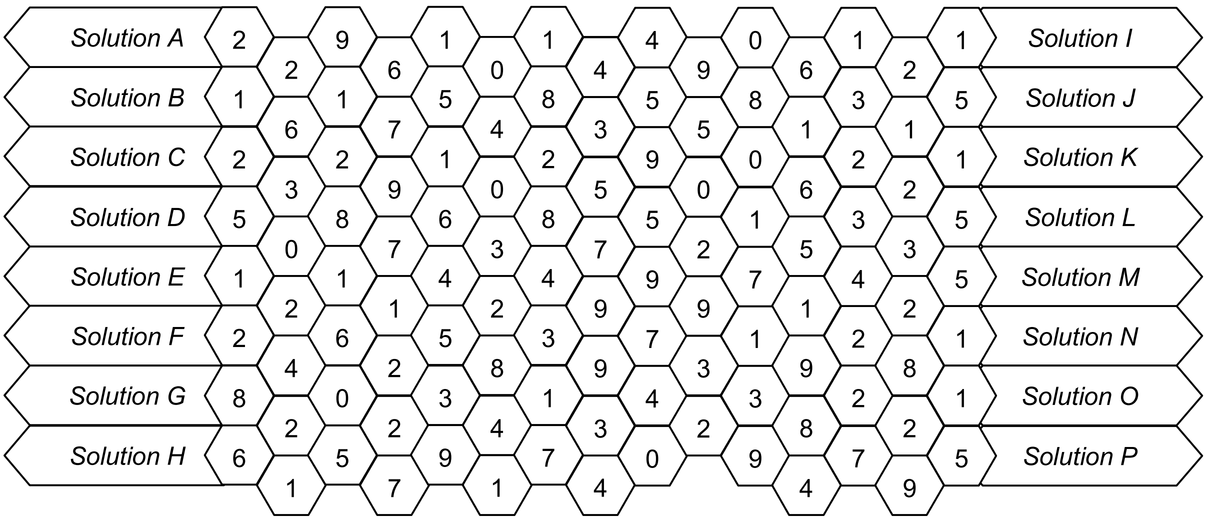
## 1.1.3. Concentration and dilution

Place the answers to calculations **1 - 9** in order from left to right in the grid below to find which two solutions *A* - *P* react together. (1 mark for each correct answer)




1. How many moles of NaCl must be dissolved in 0.5 $dm^3$ of water to make a 4 mol $dm^{-3}$ solution.

2. How many moles of NaOH must be dissolved in 25,000 $cm^3$ of water in order to make a solution with a concentration of 0.8 mol $dm^{-3}$?

3. What volume of water in $dm^3$ must 8 moles of $NaHCO_3$ be dissolved in to make a solution with a concentration of 0.25 mol $dm^{-3}$?

4. What volume of water in $cm^3$ must 3 moles of $KMnO_4$ be dissolved in, in order to make a solution with a concentration of 4 mol $dm^{-3}$?

5. A technician found that 2000 $cm^3$ of a 4 mol $dm^{-3}$ solution of copper sulphate was needed for the reaction to go to completion. How many moles of copper sulphate reacted?

6. A student needs to add $8.75 \times 10^{-3}$ moles of NaOH to neutralise the acid in his sample. How many $cm^3$ of a 0.35 mol $dm^{-3}$ solution should he add?

7. A chemist wants to dilute a stock solution of 10 mol $dm^{-3}$ NaOH to make a solution with a concentration of 1 mol $dm^{-3}$. What volume of water must be added to 100 $cm^3$ of the 10 mol $dm^{-3}$ solution?

8. Lucy wants to make up a solution with a concentration of 2 mol $dm^{-3}$. What volume of water in $dm^3$ must she add to 500 $cm^3$ of 6 mol $dm^{-3}$ stock solution?

9. Alex must add what volume of water in $cm^3$ to 45 $cm^3$ of a 9 mol $dm^{-3}$ solution of $H_2SO_4$ to make a 1.5 mol $dm^{-3}$ solution?

Which two solutions need to be mixed in order to get a reaction?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## 1.1.4. Moles summary

Mark the student's answers to the questions below (shown to the right). Mark all 10 correctly to get the full 10 marks.

**1.** Magnesium reacts with acid as shown; $Mg + 2\ HCl \rightarrow MgCl_2 + H_2$

(a) How many moles of Mg reacts with 1 mole of HCl — 1 mole

(b) How many moles of Mg must be reacted to produce 1 mole of $H_2$ — 1 mole

**2.** Potassium reacts with water to produce potassium hydroxide and hydrogen gas.

(a) Write a balanced equation for the reaction — $K + 2\ H_2O \rightarrow K(OH)_2 + H_2$

(b) How many moles of potassium must be reacted with an excess of water to produce 0.075 moles of potassium hydroxide? — 0.075 moles

**3.** The dehydration of hydrated copper sulphate is a reversible reaction;

$$CuSO_4.5H_20 \rightleftharpoons CuSO_4 + 5\ H_2O$$

(a) What mass water is produced when 0.25 moles of hydrated copper sulphate is heated? — 22.5 g

(b) What mass of hydrated copper sulphate must be heated to produce 18 g of $H_2O$? — 249.6 g

**4.** The equation for the complete combustion of methane is; $CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$

(a) How many moles of carbon dioxide would be produced by the complete combustion of 8 g of $CH_4$? — 0.5 moles

(b) What mass of oxygen is needed for the complete combustion of 32 g of methane? — 64 g

**5.** In an acid / base titration between ethanoic acid and sodium hydroxide the equation for the reaction is;

$$CH_3COOH + NaOH \rightarrow CH_3COO^-Na^+ + H_2O$$

(a) How many moles of NaOH is needed to neutralise 50 $cm^3$ of 0.1 mol $dm^{-3}$ $CH_3COOH$?

5 x $10^{-3}$ moles

(b) What volume of 0.1 mol $dm^{-3}$ ethanoic acid is needed to neutralise 75 $cm^3$ of 0.125 mol $dm^{-3}$ NaOH?

93.8 $cm^3$

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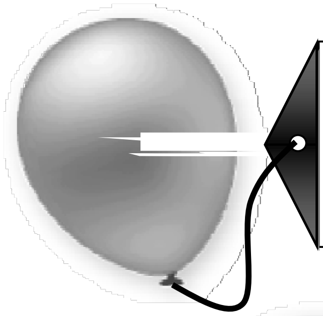
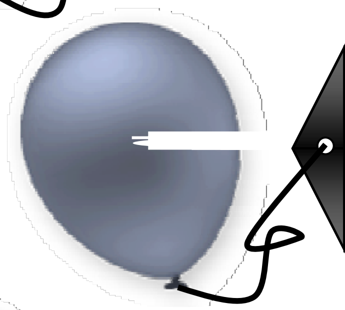
[redacted]

The following balloons [redacted] each gas in the balloon and complete the conditions each balloon must be under ($R = 8.314\ J\ K^{-1}\ mol^{-1}$)

(1 mark for each correct answer)



[redacted]



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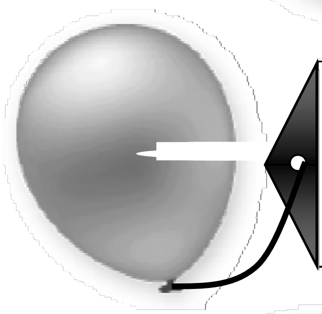

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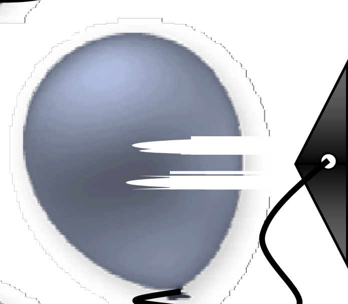

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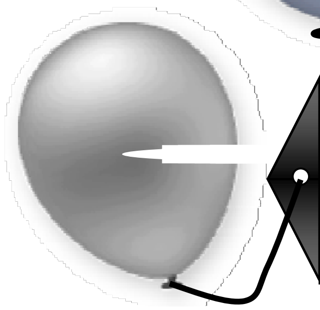

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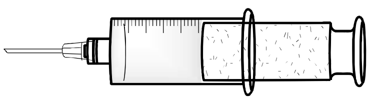
## 1.3. Molar gas volume

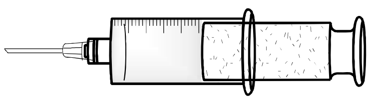
According to Avogadro's Law, as long as the pressure and temperature are kept the same, equal volumes of gases contain equal numbers of moles of gas. Under **standard temperature and pressure** (273 K and 101,325 Pa) **1 mole of any gas has a volume of 22.4 dm$^3$.**

Use Avogradro's law to find out which gas syringes contain identical numbers of moles of gas.

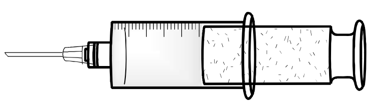
(1 mark for each correct pairing, 1 mark for correct number of moles of gas)



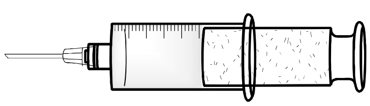
**Syringe A** contains 105 cm$^3$ of gas



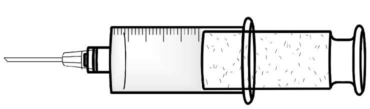
**Syringe B** contains 5.6 dm$^3$ of gas



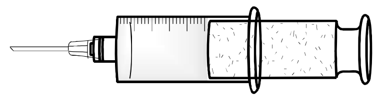
**Syringe C** contains 63 cm$^3$ of gas



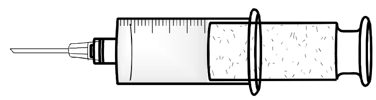
**Syringe D** contains 0.085 dm$^3$ of gas



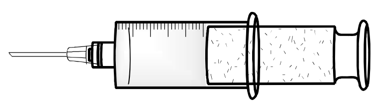
**Syringe E** contains $1.24 \times 10^{-4}$ m$^3$ of gas



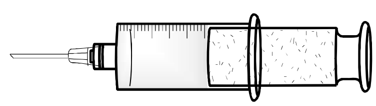
**Syringe F** contains 48 mg of ammonia



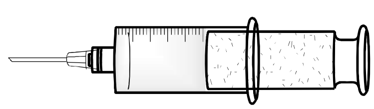
**Syringe G** contains 0.61 g of bromine



**Syringe H** contains 0.27 g of butane ($C_4H_{10}$)



**Syringe I** contains 7 g of nitrogen



**Syringe J** contains 0.16 g of air

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## 1.4. Empirical and molecular formulae

The technicians at the University have discovered a number of bottles containing amino acids which have lost their labels. In order to identify them, they carried out elemental analyses. Use the information provided to match the compound to its label;

(1 mark for each correct empirical formula, 1 mark for each correct match)

**Amino Acid A**
C 0.60 g; H 0.10 g; N 0.28 g; O 0.48 g

**Amino Acid B**
C 36 g; H 7 g; N 14 g; O 16 g

**Amino Acid C**
C 1.6 g; H 0.27 g; N 0.93 g; O 1.6 g

**Amino Acid D**
C 40.3%; H 7.6%; N 11.8%; O 40.3%

**Amino Acid E**
C 40.4 %; H 7.9 %; N 15.7 %; O 36.0 %

**Alanine**
$C_3H_7NO_2$

**Aspartic acid**
$C_4H_8N_2O_3$

**Lysine**
$C_6H_{14}N_2O_2$

**Threonine**
$C_4H_9NO_3$

**Glutamine**
$C_5H_{10}N_2O_3$


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## 1.5. Percentage yield and Atom economy

Percentage yield and atom economy are two numbers which help us gauge how efficient a reaction is for making a specific chemical. The atom economy tells us in theory how many atoms must be wasted in a reaction. The percentage yield tells us about the efficiency of the process.

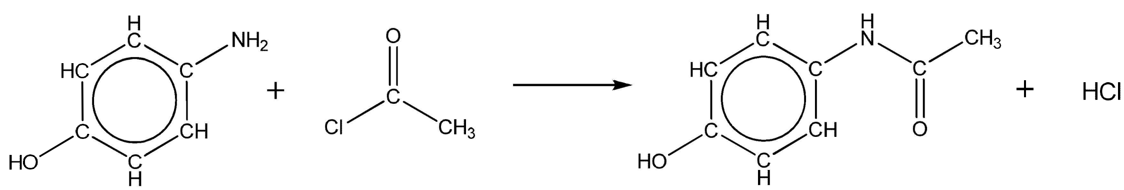
**1.** Oxygen can be produced by a number of processes. Two possible processes are shown below;

Electrolysis of water; $2\,H_2O \rightarrow 2\,H_2 + O_2$

Catalytic decomposition of water; $2\,H_2O_2 \rightarrow 2\,H_2O + O_2$

By calculating the percentage atom economy of each process, decide which process is better for producing oxygen. (3 marks)

**2.** Two students complete the synthesis of paracetamol from 4-aminophenol as shown by the equation below;




4-aminophenol + ethanoyl chloride → paracetamol + hydrogen chloride

$$HOC_6H_4NH_2 + CH_3COCl \rightarrow HOC_6H_4NHCOCH_3 + HCl$$

Both students react 2 moles of 4-aminophenol with excess ethanoyl chloride.

Student 1 makes 1.5 moles of paracetamol.

Student 2 makes 220 g of paracetamol.

Which student has the better percentage yield? (4 marks)

**3.** Copper can be made by either roasting copper sulphide or by the reduction of copper carbonate with carbon. The equations for the two processes are shown below.

| | | | | | | |
|---|---|---|---|---|---|---|
| $CuS$ | + | $O_2$ | → | $Cu$ | + | $SO_2$ |
| 0.24 moles | | | | 0.18 moles | | |
| $2\,CuCO_3$ | + | $C$ | → | $2\,Cu$ | + | $3\,CO_2$ |
| 0.56 moles | | | | 0.36 moles | | |

By comparing the percentage atom economy and the percentage yields of the processes as shown, evaluate which is the better method from an industrial viewpoint.

(3 marks)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## 1.6. Titration calculations

On Friday 23rd June the police found John Smith collapsed at his dining table over his plate of fish and chips. He had been poisoned. Police took vinegar samples from the three local fish and chip shops and, in an attempt to isolate the origin of poor John's fish and chips, analysed the concentration of the ethanoic acid in the vinegar by titration against NaOH of known concentration.

Help the police out by calculating the concentration of ethanoic acid in each of the vinegar samples;

(2 marks for each correct concentration)

**Vinegar sample taken from John Smith's dinner**

**Acid:** 25.0 $cm^3$ of vinegar
**Base:** 0.100 mol $dm^{-3}$ NaOH
**Indicator:** Phenolphthalein

| | | | |
|---|---|---|---|
| **Initial burette reading / $cm^3$** | 12.45 | 1.30 | 8.55 |
| **Final burette reading / $cm^3$** | 32.45 | 19.80 | 27.00 |
| **Titre / $cm^3$** | 20.00 | 18.50 | 18.45 |

**Vinegar sample from "The Codfather"**

**Acid:** 20.0 $cm^3$ of vinegar
**Base:** 0.150 mol $dm^{-3}$ NaOH
**Indicator:** Phenolphthalein

| | | | |
|---|---|---|---|
| **Initial burette reading / $cm^3$** | 0.05 | 0.25 | 24.50 |
| **Final burette reading / $cm^3$** | 10.50 | 10.30 | 34.60 |
| **Titre / $cm^3$** | 10.55 | 10.05 | 10.10 |

**Vinegar sample from "The Plaice"**

**Acid:** 25.0 $cm^3$ of vinegar
**Base:** 0.125 mol $dm^{-3}$ NaOH
**Indicator:** Phenolphthalein

| | | | |
|---|---|---|---|
| **Initial burette reading / $cm^3$** | 2.35 | 3.55 | 4.00 |
| **Final burette reading / $cm^3$** | 17.85 | 18.30 | 18.80 |
| **Titre / $cm^3$** | 15.50 | 14.75 | 14.80 |

**Vinegar sample from "Battersea Cod's Home"**

**Acid:** 20.0 $cm^3$ of vinegar
**Base:** 0.100 mol $dm^{-3}$ NaOH
**Indicator:** Phenolphthalein

| | | | |
|---|---|---|---|
| **Initial burette reading / $cm^3$** | 0.00 | 1.35 | 1.85 |
| **Final burette reading / $cm^3$** | 15.45 | 16.15 | 16.60 |
| **Titre / $cm^3$** | 15.45 | 14.80 | 14.75 |

John Smith's fish and chips had come from…….

………………………………………………………………………………………………………………

( 2 mark)