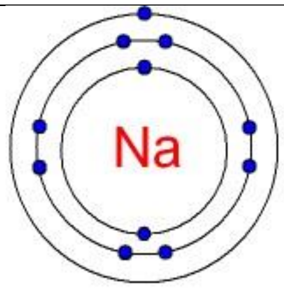
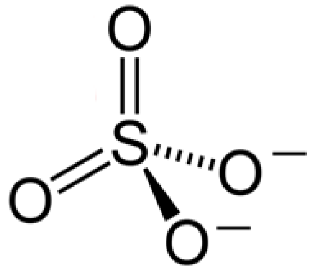
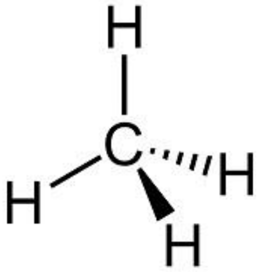
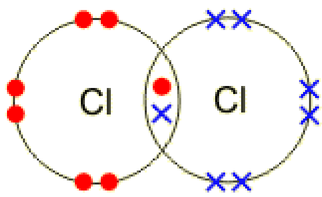
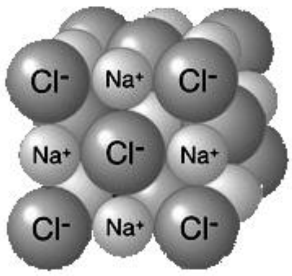
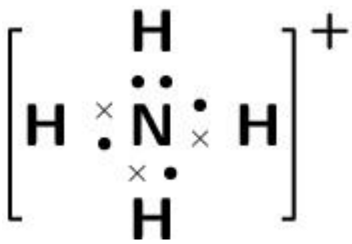
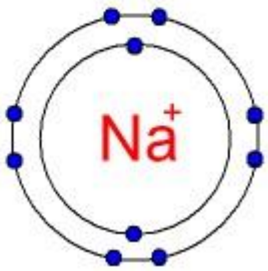
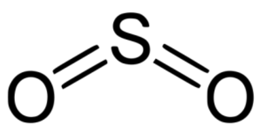
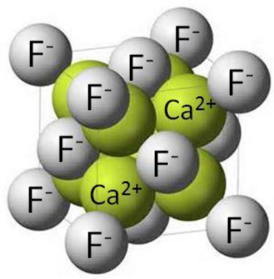
Exercise 1: Types of particles

Classify these substances as **atom**, **element**, **molecule**, **compound** or **ion**. Some substances may have more than one classification.

$O=C=O$ (a) **Compound** ✓, **molecule** ✓	 (b) **Atom** ✓	 (c) **Ion** ✓ (Molecular ion – the S and Os are bonded covalently)
Au (d) **Element** ✓	 (e) **Compound** ✓, **molecule** ✓	 (f) **Molecule** ✓ (elemental molecule)
 (g) **Compound** ✓ (ionic compound)	$N \equiv N$ (h) **Molecule** ✓ (elemental molecule)	 (i) **Ion** ✓ (Molecular ion – the N and Hs are bonded covalently)
 (j) **Ion** ✓	 (k) **Compound** ✓, **molecule** ✓	 (l) **Compound** ✓ (ionic compound)

One mark per ✓ [Total: 15]

Exercise 2: Formulae for elements

Write down the group (vertical column in the Periodic Table) to which these elements belong and their formulae.

Q	Name of element	Group	Formula	Mark
(a)	Potassium	1	K	
(b)	Nitrogen	5	N_2	
(c)	Iodine	7	I_2	
(d)	Zinc	Transition metal	Zn	
(e)	Xenon	0	Xe	
(f)	Sulfur	6	S	
(g)	Fluorine	7	F_2	
(h)	Tin	4	Sn	
(i)	Tungsten	Transition metal	W	
(j)	Phosphorus	5	P	

✓ One mark per correct row. Pay attention to the use of upper and lower cases, and subscripts. [Total: 10]

Exercise 4a: Formulae for ions

Write the formulae for the following ions, with the aid of a periodic table.

(a)	**lithium** ion	Li^+	(k)	**fluoride** ion	F^-
(b)	**magnesium** ion	Mg^{2+}	(l)	**oxide** ion	O^{2-}
(c)	**aluminium** ion	Al^{3+}	(m)	**nitride** ion	N^{3-}
(d)	**sulfide** ion	S^{2-}	(n)	**rubidium** ion	Rb^+
(e)	**hydride** ion	H^-	(o)	**manganese(II)** ion	Mn^{2+}
(f)	**chromium(III)** ion	Cr^{3+}	(p)	**hydrogen** ion	H^+
(g)	**barium** ion	Ba^{2+}	(q)	**lead(II)** ion	Pb^{2+}
(h)	**silver** ion	Ag^+	(r)	**zinc** ion	Zn^{2+}
(i)	**strontium** ion	Sr^{2+}	(s)	**iron(III)** ion	Fe^{3+}
(j)	**bromide** ion	Br^-	(t)	**phosphide** ion	P^{3-}

✓ One mark per ion: don't forget ions have charges! [Total: 20]

Exercise 5: Covalent compounds

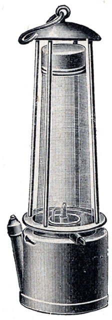
Write the formulae for the following compounds.

(a)	carbon monoxide	CO
(b)	nitrogen dioxide	NO_2
(c)	nitrogen triiodide	NI_3
(d)	sulfur dichloride	SCl_2
(e)	ammonia	NH_3
(f)	silicon tetrachloride	$SiCl_4$
(g)	phosphorus trichloride	PCl_3
(h)	dinitrogen tetroxide	N_2O_4
(i)	ethanoic acid	CH_3COOH
(j)	carbon disulfide	CS_2
(k)	methane	CH_4
(l)	dinitrogen monoxide	N_2O

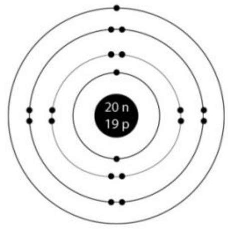
✓ One mark per compound: check that your answer is EXACTLY as given, with correct cases and subscripts!

[Total: 12]

Extension



Which famous British chemist links the last compound, a miner's safety lamp and potassium?



Sir Humphry Davy (1778 – 1829) – he worked extensively with N_2O (laughing gas), eventually becoming addicted; invented the Davy lamp used in mines to reduce the risk of methane explosions; and discovered potassium (and other Gr 1 and Gr 2 metals) by electrolysis.

Exercise 6a: Balancing equations

Balance these equations. Some of them are quite tricky, but there are *no* mistakes in the questions!

(a) Na_2O + H_2O → $2NaOH$

(b) $2KClO_3$ → $2KCl$ + $3O_2$

(c) $2H_2O_2$ → $2H_2O$ + O_2

(d) $3Fe$ + $4H_2O$ → Fe_3O_4 + $4H_2$

(e) C_2H_5OH + $3O_2$ → $2CO_2$ + $3H_2O$

(f) $(NH_4)_2\ Cr_2O_7$ → N_2 + Cr_2O_3 + $4H_2O$

(g) Sn + $4HNO_3$ → SnO_2 + $4NO_2$ + $2H_2O$

(h) PCl_5 + $4H_2O$ → H_3PO_4 + $5HCl$

(i) $2CuSO_4$ + $4KI$ → $2CuI$ + $2K_2SO_4$ + I_2

(j) PbO_2 + $4HCl$ → $PbCl_2$ + Cl_2 + $2H_2O$

✓ One mark per equation correctly balanced.

[Total: 10]

Exercise 7a: Acid reactions

1. Fill in the blanks using the words given below – you may use each word once, more than once or not at all.

carbonate	chloride	chlorine	hydrogen
hydroxide	nitrate	nitride	oxygen
salt	sulfate	sulfuric	water

acid + metal **carbonate** → **salt** + water + carbon dioxide

sulfuric acid + metal oxide → metal sulfate + **water**

nitric acid + metal **hydroxide** → metal **nitrate** + water

metal + hydrochloric acid → metal **chloride** + **hydrogen**

✓ One mark for each blank correctly filled [Total: 8]

2. Each of the following equations contains at least one error or omission. Circle the mistakes and rewrite the equations correctly.

(a) The reaction between aluminium hydroxide and hydrochloric acid

$AlOH_3 + 3HCl \rightarrow Al_3Cl + 3H2O$

✓ Missing bracket around OH

✓ Error in formula for aluminium chloride

✓ Formatting incorrect – 2 should be subscripted

$$Al(OH)_3 + 3HCl \rightarrow AlCl_3 + 3H_2O$$ ✓

(b) The reaction between potassium and sulfuric acid

$K_2 + H_2SO_4 \rightarrow K_2SO_4 + 2H$

✓ Incorrect formula for a metal / error in writing numbers in balancing

✓ Formula for hydrogen gas is H_2!

$$2K + H_2SO_4 \rightarrow K_2SO_4 + H_2$$ ✓

(c) The reaction between sodium carbonate and nitric acid

na?Co3 + $H_2NO_3 \rightarrow$ naNO^3 + H_2O + CO_2

3 formatting errors: the first letter of an element must be uppercase (applies to ✓Na and ✓O), ✓numbers in formulae must be subscripted.

Incorrect formula for ✓ sodium carbonate and ✓ nitric acid

✓ CO_2 missing as a product

Equation not balanced

$$Na_2CO_3 + 2HNO_3 \rightarrow 2NaNO_3 + H_2O + CO_2$$ ✓

(d) The reaction between ammonium hydroxide and sulfuric acid

$Nh_3OH + H_2SO_4 \rightarrow Nh_3SO_4 + H_2$

✓ The ammonium ion is NH_4^+ - errors in formatting and number of Hs

✓ Wrong formula for ammonium sulfate (charges not balanced)

✓ Wrong product – water, not hydrogen

$$2NH_4OH + H_2SO_4 \rightarrow (NH_4)_2SO_4 + 2H_2O$$ ✓

✓ One mark per point [Total: 18]

Exercise 8: Significant figures

1. Explain why 3.99521 to 3 sig figs is 4.00.

   The 4th figure is 5, so needs to round up.

   The 3rd figure is 9, so rounds up to 10; causing the 2nd figure to round up to 10 as well.

   This results in the first figure rounding to 4.

   The 2nd and 3rd figures are known to be zero.

   These "trailing zeros" are significant, hence 4.00 to 3sf.

2. To how many significant figures are the following quoted?

(a)	2048	**4sf**	(d)	0.00395	**3sf**
(b)	9.00043	**6sf**	(e)	0.05030	**4sf**
(c)	0.0008	**1sf**	(f)	650000	**at least 2sf, but hard to be sure**

3. Re-write the following to the number of significant figures required.

(a)	5462 (to 2sf)	**5500**	(d)	0.039214 (to 3sf)	**0.0392**
(b)	20543 (to 2sf)	**21000 or 2.1×10^4**	(e)	0.0056972 (to 3sf)	**0.00570**
(c)	1.5952 (to 3sf)	**1.60**	(f)	470356 (to 3sf)	**470000 or 4.70×10^5**

4. Calculate the following to **an appropriate number** of significant figures.

(a)	3.854 + 2.06	**5.91 (3sf)**
(b)	6.52 - 2.7	**3.8 (2sf)**
(c)	1.48 x 6.2	**9.2 (2sf)**
(d)	19.5 ÷ 0.284	**68.7 (3sf)**

✓ One mark per answer to Q 2 - 4 [Total: 16]

Exercise 9: Standard form

1. Write the following numbers in standard form to 3 significant figures.

(a) 123456 **1.23×10^5**

(b) 45062 **4.51×10^4**

(c) 0.058345 **5.83×10^{-2}**

(d) 0.000259631 **2.60×10^{-4}**

✓ One mark per answer [Total: 4]

2. Write the following numbers in longhand (“normal numbers”).

(a) 1.36×10^4 **13600**

(b) 5.75×10^{-3} **0.00575**

(c) 6.02×10^{23} **602 000 000 000 000 000 000 000**

(d) 1.60×10^{-19} **0.000 000 000 000 000 000 160**

✓ One mark per answer [Total: 4]

3. The following values in metres link to the given quantities, but they have been mixed up. Rank them in order of size in the table overleaf, and then use them to complete the calculations that follow.

2.75×10^{-15}	Length of a butane molecule
5.48×10^{-10}	Radius of a bonded carbon atom
7.50×10^{-11}	Radius of a carbon nucleus
8.78×10^{-16}	Radius of a proton

Size of particles ✓ Table correctly filled in

Size	Value in metres	Quantity
Smallest	**8.78×10^{-16}**	**Radius of a proton**
↑	**2.75×10^{-15}**	**Radius of a carbon nucleus**
↓	**7.50×10^{-11}**	**Radius of a bonded carbon atom**
Biggest	**5.48×10^{-10}**	**Length of a butane molecule**

Give your answers to these calculations to 3 significant figures.

(a) The diameter of a bonded carbon atom.

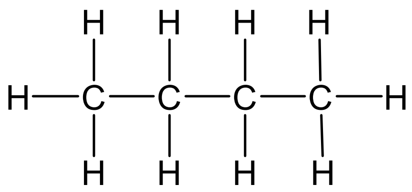
$= 2 \times \text{radius} = 2 \times 7.50 \times 10^{-11} = 1.50 \times 10^{-10}$ m ✓

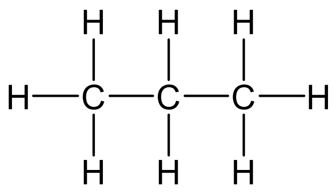
(b) The width of a carbon nucleus if the width of a proton is taken off.

Width = diameter = 2 x radius

$(2 \times 2.75 \times 10^{-15}) - (2 \times 8.78 \times 10^{-16}) = 3.74 \times 10^{-15}$ m ✓

(c) Butane has the structure on the left below, whilst propane is on the right:





Estimate the length of a propane molecule.

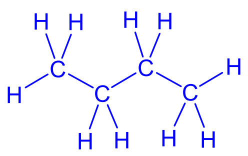
A propane molecule is a bonded C atom shorter than butane.

$5.48 \times 10^{-10} - (2 \times 7.50 \times 10^{-11}) = 3.98 \times 10^{-10}$ m ✓

(d) The length of a butane molecule is equivalent to how many bonded C atoms lined up side by side?

$$\frac{5.48 \times 10^{-10}}{2 \times 7.50 \times 10^{-11}} = 3.65$$ ✓

Why do you think this is less than the width of 4 bonded C atoms?



The actual arrangement of the atoms is not in a straight line, but in a zigzag, so the length from end to end is shorter.

✓ Sensible suggestion along these lines

[Total: 6]

Exercise 10: Rearranging algebraic equations

Answers in blue. Applications (extension) in green.

(a) Find $mass$ if $moles = \frac{mass}{molar\ mass}$

$mass = moles \times molar\ mass$

Relates mass with amount of substance (moles)

(b) Find $volume$ if $number\ of\ moles = concentration \times volume$

$$volume = \frac{number\ of\ moles}{concentration}$$

Relates amount of solute in a solution

(c) Find $molar\ volume$ if $moles = \frac{volume}{molar\ volume}$

$$molar\ volume = \frac{volume}{moles}$$

Relates gas volume with amount of gas

(d) Find ΔT if $Q = mc\Delta T$

$$\Delta T = \frac{Q}{mc}$$

Links heat released/absorbed in a reaction with temperature change

(e) Find $[H^+]$ if $K_a = \frac{[H^+][A^-]}{[HA]}$

$$[H^+] = K_a \times \frac{[HA]}{[A^-]}$$

Shows the extent of dissociation of a weak acid

(f) Find $[HI]$ if $K_c = \frac{[HI]^2}{[H_2][I_2]}$

$$[HI] = \sqrt{K_c [H_2][I_2]}$$

K_c is the equilibrium constant for a reversible reaction.

(g) Find ΔH if $\Delta G = \Delta H - T\Delta S$

$$\Delta H = \Delta G + T\Delta S$$

Shows the relationship between ΔG (free energy change), ΔH (enthalpy change), ΔS (entropy change) and temperature, T.

(h) Find ΔS if $\Delta G = \Delta H - T\Delta S$

$\Delta S = \frac{\Delta H - \Delta G}{T}$ As (g)

✓ One mark per rearrangement [Total: 8]

Exercise 11: Maths quiz hints

Hints for how to handle this type of question:

1. Look carefully at the information given in the questions.
2. Use the **units** to help you decide what sorts of *quantities* you have been given, eg *amount* if the unit is mol, *volume* if the unit is cm^3 or dm^3, *concentration* if the units are mol dm^{-3}. Label the quantities.
3. Look at the formulae provided and identify which to use – you need the one for which you know 2 values and are asked to find the third.
4. **Rearrange** the formula for the variable you need, then substitute in the numerical values.

Exercise 11: Maths quiz

For each question, award

✓ one mark for rearranging the equation correctly and substituting in the given values

✓ one mark for the correct final answer to the appropriate number of sig figs.

[Total: 10]

A. Find the **amount**, in mol, of NaCl in 10.0g of NaCl, given its molar mass is 58.5 g mol^{-1}. Give your answer to 3sf.

We have the **mass** (10.0g) of NaCl, and its **molar mass** (58.5 g mol^{-1}), so we use equation ① to find **amount**.

$$amount = \frac{mass}{molar\ mass} = \frac{10.0}{58.5} = 0.1709401709$$

……… **0.171 (3sf)** ………. mol

B. Find the **volume**, in cm^3, of 4.246 x 10^{-4} mol of a gas, given the molar volume is 24000 cm^3 mol^{-1}. Give your answer to 4sf.

We have the **amount** (4.246 x 10^{-4} mol) and **molar volume** (24000 cm^3 mol^{-1}) of a **gas**, so we rearrange equation ② to find the **volume**.

$$volume = amount \times molar\ volume$$

$$= 4.246 \times 10^{-4} \times 24000 = 10.1904$$

……… **10.19 (4sf)** ………. cm^3

C. A 0.330 dm^3 can of Coke contains 0.102 mol sucrose. What is the **concentration**, in mol dm^{-3}, of sucrose in this can of Coke? Give your answer to 3sf.

We have the **amount** (0.102 mol) and **volume** (0.330 dm^3), so we rearrange equation ③ to find the **concentration**.

$$concentration = \frac{amount}{volume} = \frac{0.102}{0.330} = 0.3090909091$$

……… **0.309 (3sf)** ………. mol dm^{-3}

D. 76.000 cm^3 CO_2 was collected in an experiment at room temperature and pressure (RTP). The molar volume of any gas is 24000 cm^3 mol^{-1} at RTP. What is the **amount**, in mol, of CO_2 collected in this experiment? Give your answer in *standard form* to 5sf.

We have the **volume** of a **gas** (76.000 cm^3) and its **molar volume** (24000 cm^3 mol^{-1}), so we use equation ② to find the **amount**.

$$amount = \frac{volume}{molar\ volume} = \frac{76.000}{24000} = 3.166666667 \times 10^{-3}$$

……… **3.1667 x 10^{-3} (5sf)** ……… mol

Answer must be in standard form

E. A chemist needs 1.25 x 10^{-3} mol of $KMnO_4$ in an experiment. He has a solution of $KMnO_4$ of 2.25 x 10^{-2} mol dm^{-3} concentration. Calculate the **volume**, in dm^3, of this solution he needs to 3sf.

We have the **amount** of solute (1.25 x 10^{-3} mol) and **concentration** (2.25 x 10^{-2} mol dm^{-3}) of a solution, so we rearrange equation ③ to find the **volume**.

$$volume = \frac{amount}{concentration} = \frac{1.25 \times 10^{-3}}{2.25 \times 10^{-2}} = 0.05555555556$$

……… **0.0556 (3sf)** ……… dm^3

You will check your answers to F – J when you join us in September.

Prac: Observations exercise

Watch the video found on our HRChem channel on Youtube.

https://youtu.be/F-gspJFPzxo

Record your observations of the different reactions in the table below.

Expt	Observations	Mark
A	2 colourless solutions✓ mixed to form a yellow precipitate✓ (accept solid). We know it was a yellow *solid* because the solution was no longer see-through (or "clear").	/2
B	A purple solution✓ was added dropwise to a colourless solution✓. The purple solution was decolourised✓ (or you can say "the purple solution went colourless").	/3
C	A colourless liquid✓ (or solution) was added to an orange solution✓. On heating in the hot water bath, the solution went from orange to green✓.	/3
D	A white solid✓ was added to a colourless solution✓. Effervescence✓ occurred, the (white) solid disappeared✓ and a colourless solution remained. The colourless gas✓ produced was bubbled through a colourless solution✓ of limewater. A white precipitate formed✓. Note to record the observations in both test tubes. You may have been taught to say the "limewater went cloudy". The cloudiness is due to the formation of a white solid (calcium carbonate), so should be noted as a white precipitate. You may have correctly deduced that this result means carbon dioxide has been produced. However this is a *deduction*, not an *observation*, so is not relevant for this exercise.	/7
E	A colourless solution✓ was added to a pale blue solution✓. The solution went a darker blue, then a pale blue precipitate (or "solid") was formed✓ on shaking. On further addition of the colourless solution, the pale blue precipitate dissolved✓ to form a darker blue solution✓.	/5

Key point is to record colour and state of the chemicals, at the start, the end and the middle (if interesting!). For this exercise, we will accept "liquid" rather than "solution" as you don't know whether the substances have been dissolved in water.

✓ One mark per observation – remember both colour and state are needed

NB "clear" is NOT a substitute for "colourless"

[Total: 20]