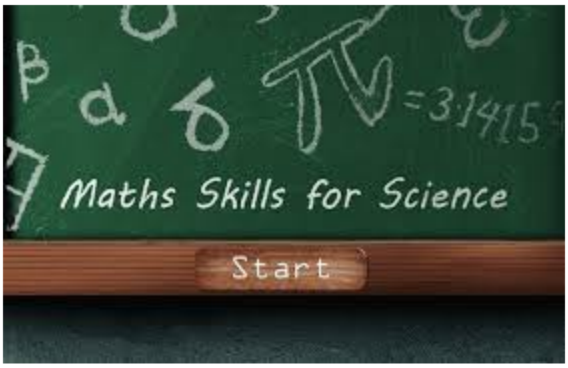
A LEVEL CHEMISTRY

MATHS SKILLS

WORKBOOK



A LEVEL CHEMISTRY MATHS SKILLS

- Recap from GCSE giving maths skills needed for A Level Chemistry.
- Read through the attached notes to support the tasks on either Isaac Chemistry or a worksheet (attached at the end of the booklet).
- Isaac Chemistry self marking, worksheet mark schemes attached.

Join Isaac Chemistry

- Use the following link; https://isaacphysics.org/account?authToken=8M78VY **OR**
- Go onto Isaac Chemistry and get an account (please note you can use your Isaac Physics account)
- Use the menu button to go into 'My Account' and 'Teacher connections'
- Join the group using the code **8M78VY**
- Use the menu button to go into 'My Boards' and work your way through the boards. Please note that worked examples are given in the booklet

	Topic	
1.	**General maths skills;**	
a)	Standard form and significant figures	Isaac Chemistry B1
b)	Unit and volume conversions	Isaac Chemistry B2
c)	Rearranging equations	Worksheet
d)	Empirical formula (not covered at GCSE)	Isaac Chemistry A1
2.	**Mole and Avagadro**	
a)	Avagadro constant	Worksheet
b)	Gases	Isaac Chemistry B3
c)	Solids	Isaac Chemistry B4
d)	Solutions	Isaac Chemistry B5
e)	Reacting masses	Isaac Chemistry B6
3.	**Density**	
4.	**% calculations**	
a)	% yield/atom economy	Worksheet
b)	% uncertainty	
5.	Graphs – drawing tangents	Worksheet

1. General Maths Skills

1a) <u>Standard form</u> (removing zeros)

Number between 1 and 10 → $A \times 10^{n}$ ← Number of places the decimal point would have to move if the number was written in full

Eg. 602 000 000 000 000 000 000 000 = 6.02×10^{23}

0.000 000 000 010 0 = 1.00×10^{-14}

<u>Significant figures</u>

Give your answers to the same number of significant figures as given in the question. The standard is 3 significant figures. <u>Exception;</u> Relative atomic mass is always 1 dp. Ensure you do not round in a calculation until the very last number.

- Start counting from the 1st non-zero digit eg. 0.000701 is to 3 sig figs
- Stop counting at the last non-zero digit (or last digit after decimal place)
    - eg. 187.23 5 sig figs
    - 9.005 4 sig figs
    - 448000g 3 sig figs
    - 159.0 4 sig figs

1b). <u>Units and volume conversions</u>

When identifying the values to use in equations, the new specification has significantly expanded the maths skills required at A level. This necessitates a confidence in substituting numbers **based on their units only.**

Eg Calculate the mass**, in kg**, of a single $^{52}Cr^{+}$ ion. Assume that the mass of a $^{52}Cr^{+}$ ion is the same as that of a ^{52}Cr atom. (The Avogadro constant L = 6.022×10^{23} **mol^{-1}**)

Mass = mole x Mr

$$= \frac{1}{6.022 \times 10^{23}} \times \frac{52}{10000}$$

All students must know which volume unit is required in a calculation and be able to convert between them.

cm^3	dm^3	m^3
1×10^{1}	1×10^{1}	1×10^{1}
1	1000	1000,000

1c) <u>Rearranging equations</u>

$$\text{Mole} = \frac{\text{mass}}{\text{Mr}}$$

Solve for mass;

To remove Mr, X both sides by Mr (equation so must do same for both sides) so that it will cancel

Mr x Mole = $\frac{\text{mass}}{\cancel{\text{Mr}}} \times \cancel{\text{Mr}}$

Mass = Mr x Mole

Solve for Mr;

To get Mr as numerator, X both sides by Mr (equation so must do same for both sides)

Mr x Mole = $\frac{\text{mass}}{\sout{\text{Mr}}}$ x ~~Mr~~

Mr x Mole = mass

To remove moles, ÷ both sides by moles

$\frac{\text{Mr x } \sout{\text{Mole}}}{\sout{\text{Mole}}} = \frac{\text{mass}}{\text{Mole}}$

Mr = $\frac{\text{mass}}{\text{Mole}}$

1d) <u>Empirical formula</u>

Calculating from given masses;

A sample of titanium oxide was analysed and found to contain 0.958g of titanium and 0.640g of oxygen. Calculate the empirical formula of the compound (Ar Ti=47.9, O=16.0)

Always lay out in the same way;

	Ti	O
1. Mass (info given)	0.958g	0.64g
2. Ar	47.9	16
3. Moles (mass/Ar)	0.02	0.04
4. Molar ratio (divide smallest into rest)	0.02/0.02 = 1	0.04/0.02 = 2

Therefore ratio of 1xTi atom for every 2xO atom = EF = TiO_2 (note – frequent error writing as Ti_2O)

Calculating from given percentages;

A sample had 20.2% magnesium, 26.7% sulphur and 53.1% oxygen. Calculate the empirical formula of the compound (Ar Mg=24.3, S=32.10, 0=16.0)

	Mg	S	O
1. Mass	20.2	26.7	53.1
2. Ar	24.3	26.7	16.0
3. Moles (mass/Ar)	0.831	0.832	3.319
4. Molar ratio	0.831/0.831 = 1	0.832/0.831 = 1	3.319/0.831 = 4

Therefore EF = $MgSO_4$

2. Mole and Avagadro

2a) Avagadro constant (worksheet)

- Relative atomic mass is the mass of an atom relative to an atom of **Carbon 12**
  ie an atom of Magnesium with M_r of 24 is twice as heavy as an atom of C12
- Because of the stoichiometric relationship between atoms, molecules and compounds in a balanced equation, this was expanded to say 1 mole of a substance (in g) has the same number of particles (6.02×10^{23}) as atoms in 12g of C12. 6.02×10^{23} is Avagadro's constant
  ie 1 mole of Mg = 24g, 1 mole of C=12g and they both have 6.02×10^{23} particles
- I mole of any entity contains 6.02×10^{23} of that entity ie. 1 mole of carbon dioxide molecules will contain 6.02×10^{23} molecules, 1 mole of electrons contains 6.02×10^{23} electons

Number of particles = amount of substance (in moles) x Avagadro's constant

2b) Gases

Equal volumes of gases measured under the same conditions of temperature and pressure contain equal numbers of molecules (or atoms if the gas is monatomic)

1 mole of any gas at room pressure (1atm) and room temp (25°C) will have the volume of 24 dm³

Eg. If 500cm³ of methane is burn at 1atm and 300K what volume of oxygen would be needed and what volume of CO_2 would be given off?

$CH_4 (g) + 2O_2 (g) \rightarrow CO_2 (g) + 2H_2O (l)$

500 cm³ of CH_4 react with (500x2) 1,000 cm³(1 dm³)of O_2

Ratio CH_4:CO_2 1:1 so 500 cm³ of CO_2 produced

For gases –	Moles (mol) =	$\frac{\text{vol}/1000 \ (\text{cm}^3)}{24 \ (\text{dm}^3)}$

2c) Solids

For solids and gases –	**Moles** (mol) = $\frac{\textbf{mass} \text{ (m)}}{\textbf{Mr} \text{ (relative atomic mass, no units)}}$

eg. What is the number of moles in 35.0g of $CuSO_4$?

Moles = mass/Mr
= 35.0/(63.5+32+16x4)
= 0.219 moles

2d) Solutions

For solutions -	**Moles** (mol) = **Conc** (mol dm^{-3} or M) **x volume** (dm^3)
	Conc (in g dm^{-3}) = conc (n mol dm^{-3}) x Mr

eg 1. What is the concentration of solution made by dissolving 5.00g of Na_2CO_3 in 250 water?

Moles = mass/Mr
= 5.00/(23x2+12+16x3)
= 0.0472 mol

Conc = moles/volume
= 0.0472/**0.25**
= 0.189 mol dm^{-3}

2. How many chloride ions are there in a $25cm^3$ solution of magnesium chloride of concentration 0.400 mol dm^{-3}

Moles = conc x volume
= 0.40 x 0.025
= 0.01 mol

2 moles of chloride ions for every mole of $MgCl_2$

Ions of Cl = moles x 6.02 x 10^{23}
= 0.02 x 6.02 x 10^{23}
= 1.20 x 10^{22} (3 sig figs)

2e) <u>Reacting masses</u>

$N_2 + 3H_2 \rightarrow 2NH_3$

The balancing (stoichiometric) numbers are mole ratios eg I mole of N_2 reacts with 3 moles of H_2 to produce 2 moles of NH_3.

Typically, you are given a quantity of one substance and asked to work out a quantity for another substance in the reaction.

The steps to follow are;

- Work out the number of moles of the quantity given
- Use moles of initial substance in equation to get moles of 2nd substance
- Convert moles of 2nd substance into quantity wanted eg mass, concentration, volume of gas.

Eg. What mass of copper would react completely with 150 of 1.60M nitric acid?

$3Cu + 8HNO_3 \rightarrow 3Cu(NO_3)_2 + 2NO + 4H_2O$

1. Moles of nitric acid
   Moles = conc x vol
   = 1.6 x 0.15 = 0.24mol
2. From the equation, 8:3 ration nitric acid:copper
   So 0.09mol of Cu

3. Mass Cu = moles x Mr
   = 0.09 x 63.5 = **5.71g**

3. <u>Density</u>

Density = mass / volume

Density is usually g cm^{-3}, Mass in g and Volume in cm^{-3} however use the data given to identify if different units are required.

Eg. How many molecules of ethanol are there in a 0.500 dm^3, of ethanol (CH_3CH_2OH) liquid? The density of ethanol is 0.7879 g cm^{-3}

Mass = density x volume
= 0.789 x 500
= 394.5g

Moles = mass/Mr
= 394.5/46.0
= 8.576 mol

Molecules = mol x 6.02 x 10^{23}
= 8.576 x 6.02 x 10^{23}
= 5.16 x 10^{23} (3 sig fig)

4. % Calculations

4a) % yield and atom economy

% yield = $\frac{\text{actual yield}}{\text{theoretical yield}}$ x 100

atom economy = $\frac{\text{mass of useful products}}{\text{mass of all reactants}}$ x 100

Do take account balancing numbers when working out % atom economy

1. What is the % atom economy for the following reaction where Fe is the desired product assuming the reaction goes to completion?

$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$

% atom economy = $\frac{(2x55.8)}{(2x55.8+3X16) +3x(12+16)}$ x 100 = 45.8%

2. 25.0g of Fe2O3 was reacted and it produced 10.0g of Fe. What is the percentage yeild?
$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$

a) Maximum mass of Fe that could be produced;
Moles = mass/Mr
= 25.0/159.6 = 0.1566 mole

b) 1mole Fe_2O_3 : 2 moles Fe
0.1566 Fe_2O_3 : 0.313 moles Fe

c) Mass of Fe
Mass = molesxMr
= 0.313x55.8 = 17.5g

d) % yield = actual yield/theoretical yield) x 100
= (10/17.5) x 100 = 57.1%

4b) % uncertainty

With using any piece of equipment there is an uncertainty of $^{+}/_{-}$ 0.5 of the smallest scale reading.

% uncertainty = $\frac{\text{uncertainty}}{\text{Measurement made on apparatus}}$ x 100

If more than 1 reading is taken, the uncertainty increases accordingly.

1. What is the % uncertainty when 25cm^3 of a liquid was measured using a pipette with an uncertainty of $^{+}/_{-}$ 0.1 cm^3?

   % uncertainty = 0.1/25 x 100 = 0.4%

2. 2 concordant titres of 25.5 cm and 25 were taken giving an average titre of 25.25. If the uncertainty of the burette is $^{+}/_{-}$ 0.15 cm^3, what is the % uncertainty?

   % uncertainty = 0.15x2/25.25 x 100 = 1.19%

To reduce the uncertainty either;

- replace a measuring cylinder with pipettes or burettes with lower apparatus uncertainty ie decrease the numerator
- increase the titre ie increase the denominator. For a titration; increase the volume and concentration of the substance in the conical flask or decrease the concentration of the substance in the burette
- use a more accurate balance or a larger mass when weighing a solid

If the % uncertainty due to the apparatus < % difference between the actual value and the calculated value then there is a discrepancy in the result due to experimental errors

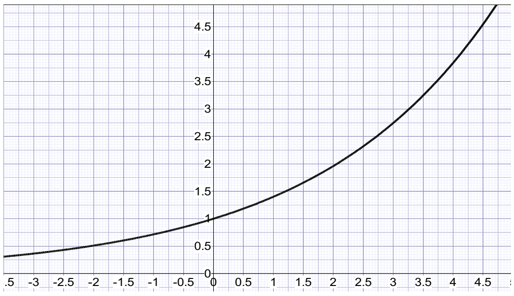
If the % uncertainty due to the apparatus > % difference between the actual value and the calculated value then there is no discrepancy and all errors are due to sensitivity of the equipment

5. Graphs – drawing tangents

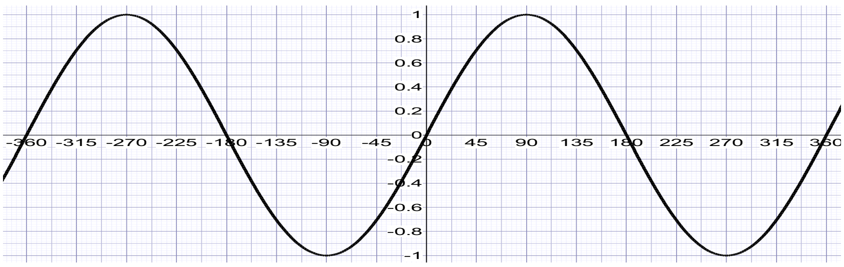
For linear graphs the gradient is constant. It never changes. For a curve, the gradient changes as you move along the graph. It could get bigger/smaller, or it could change from positive to negative.

For calculating rates, we need to be able to calculate the gradient at a specific point.

eg. this curve has a positive correlation (goes from low value to high value, left to right) so has a positive gradient



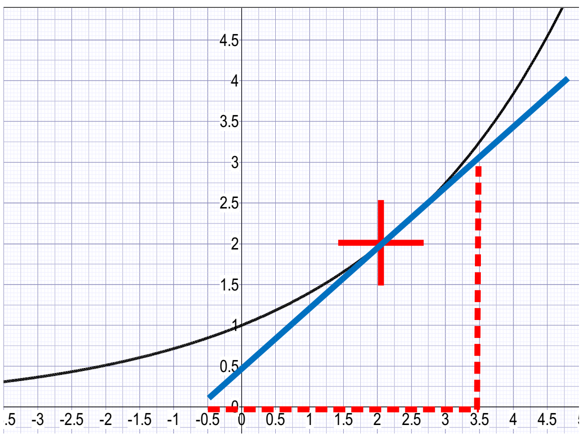
This curve has an alternative positive correlation/gradient then negative correlation/gradient.



Calculating a gradient

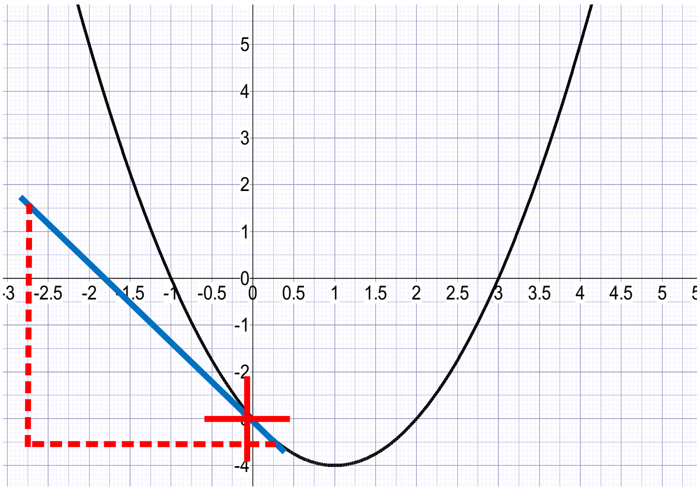
1. Draw a straight line at the point you wish to draw a tangent parallel to the line
2. Calculate the gradient by m= $\frac{\text{change in y}}{\text{change in x}}$
3. Note the 'triangle' that you use for the values can be as big or as small as you wish. However use values that are easy to read off the graph. Tangent at 2,2;

$$m = \frac{(3-0)}{3.5-(-0.5)} = \frac{3}{4} = 0.75$$



Tangent at 0, -3

$$m = \frac{-4-1}{0.5-(-2.5)} = \frac{-5}{3} = 1.67$$



Worksheet 1c); Rearranging Equations

Density

Density = m / V

Density (g/cm^3) = mass (g) / volume (cm^3)

Temperature

°F = (9/5 x °C) + 32

Molar equation

$n = m / M_r$

Number of moles = mass (grams) / molecular weight

M_r of; water = 18, carbon dioxide = 44,

Ideal Gas Law

pV = nRT

Pressure (kilopascals) x volume (m^3) = number of moles x gas constant (8.31) x absolute temperature (kelvin)

Room temp = 298 K

Equations of Motion

$$
\begin{aligned}
v &= u + at \\
s &= \tfrac{1}{2}(u + v)t \\
s &= ut + \tfrac{1}{2}at^2
\end{aligned}
$$

Where;
s = the distance travelled (m)
u = the initial velocity (m/s)
v = the final velocity (m/s)
a = acceleration (m/s^2)
t = time taken (s)

Questions

In your workings, rearrange the formula then calculate the answer.

1. Lead has a density of 11.34 g/cm^3. How much will a cubic metre of lead weigh, in kilograms?

2. Balsa wood has a density of 0.17 g/cm^3. If I have a block that weighs 1kg, what volume does it have?

3. Normal body temperature is about 98°F. How much is this in Celsius?

4. Absolute zero temperature occurs at -459.67°F. How much is this in Celsius?

5. In 2007 the UK's carbon dioxide emission in moles was 1.226×10^{13}. How many metric tons does this represent? (One tonne = 1000kg)
How many moles of hydrogen gas are in a 3.1 m^3 sample measured at 300 kPa, which is kept at room temperature?

6. A 0.5 m^3 container holds 0.05 moles of O_2 at room temperature. What pressure does the gas exert on the inside of the container?

7. A cyclist accelerates from 3 m/s to 5m/s taking him 10 seconds to do so. What is his acceleration?

8. A F1 car accelerates in a straight line for 200m, which takes 4 seconds. If it's initial speed was 30 m/s how fast was it travelling at the end of the straight?

9. A ball is dropped from the leaning tower of Pisa, at a height of 50m from the ground. The ball is dropped from rest and falls freely under gravity. How long will it be before the ball hits the ground? (Gravity causes acceleration of 9.8 m/s^2)

Worksheet 2a); Avagadro Constant (L=6.022x10^{23} mol^{-1})

1. Calculate the number of atoms in
a) 1.00 mole of lithium
b) 1.00 mole of tungsten
c) 1.00 mole of aluminium
give your answer to 3 significant figures

2. Calculate the number of atoms in
a) 0.10 moles of carbon
b) 2.50 moles of sulfur
c) 0.75 moles of magnesium
give your answer to 3 significant figures

3. Calculate the number of particles in
a) 1.00 mole of sodium ions
b) 1.00 mole of nitrogen molecules
c) 1.00 mole of magnesium ions
give your answer to 3 significant figures

4. Calculate the number of particles in
a) 2.00 moles of electrons
b) 1.50 mole of oxide ions
c) 0.20 moles of lithium ions

5. Calculate the number of particles in 48.6g of magnesium atoms

6. Calculate the mass, in kg, of one atom of ^{49}Ti. The avagadro constant L=6.022x10^{23} mol^{-1}

Worksheet 4a) Percentage yield and atom economy

1. Calculate the percentage yield of a reaction that has a theoretical yield of 4.75 moles of product and an actual yield of 3.19 moles of product. Give you answer to three significant figures.

2. Calculate the percentage yield of a reaction that has a theoretical yield of 3.00 moles of product and an actual yield of 2.75 moles of product. Give you answer to three significant figures.

3. Calculate the percentage yield of a reaction that has a theoretical yield of 12.00 moles of product and an actual yield of 6.25 moles of product. Give you answer to three significant figures.

The following have a reactant in excess and a limiting reagent. The limiting reagent will be used up first.

4. An excess of zinc is added to 25.0cm^3 of 1.0 mol dm^{-3} iron(I) sulfate solution.

$Zn(s) + FeSO_4(aq) \rightarrow ZnSO_4(aq) + Fe(s)$

1.16g of iron is produced. Calculate the percentage yield for this reaction.

5. An excess of magnesium is added to 50.0cm^3 of 1.0mol dm^{-3} aqueous hydrochloric acid solution.

Mg(s) + 2HCl(aq) → MgCl2(aq) + H2(g)

0.953g of magnesium chloride is produced. Calculate the percentage yield for this reaction.

6. An excess of magnesium is added to 100.0cm^3 of 0.5mol dm^{-3} iron(I) sulfate solution.

$Mg(s) + FeSO_4(aq) \rightarrow MgSO_4(aq) + Fe(s)$

0.558g of iron is produced. Calculate the percentage yield for this reaction.

<u>Atom Economy</u>

1. A chemist added chlorine to ethene to produce 1,2-dichloroethane.
$CH_2CH_2 + Cl_2 \rightarrow CH_2ClCH_2Cl$
Determine the % atom economy of this reaction. The molar mass of 1, 2-dichlorethane = 99.0g mol^{-1}

2. A chemist adds bromine to propene to produce 1,2-dibromopropane.
$Br_2 + CH_3CHCH_2 \rightarrow CH_3CHBrCH_2Br$
Determine the % atom economy of this reaction. The molar mass of 1,2-dibromopropane = 201.8g mol^{-1}

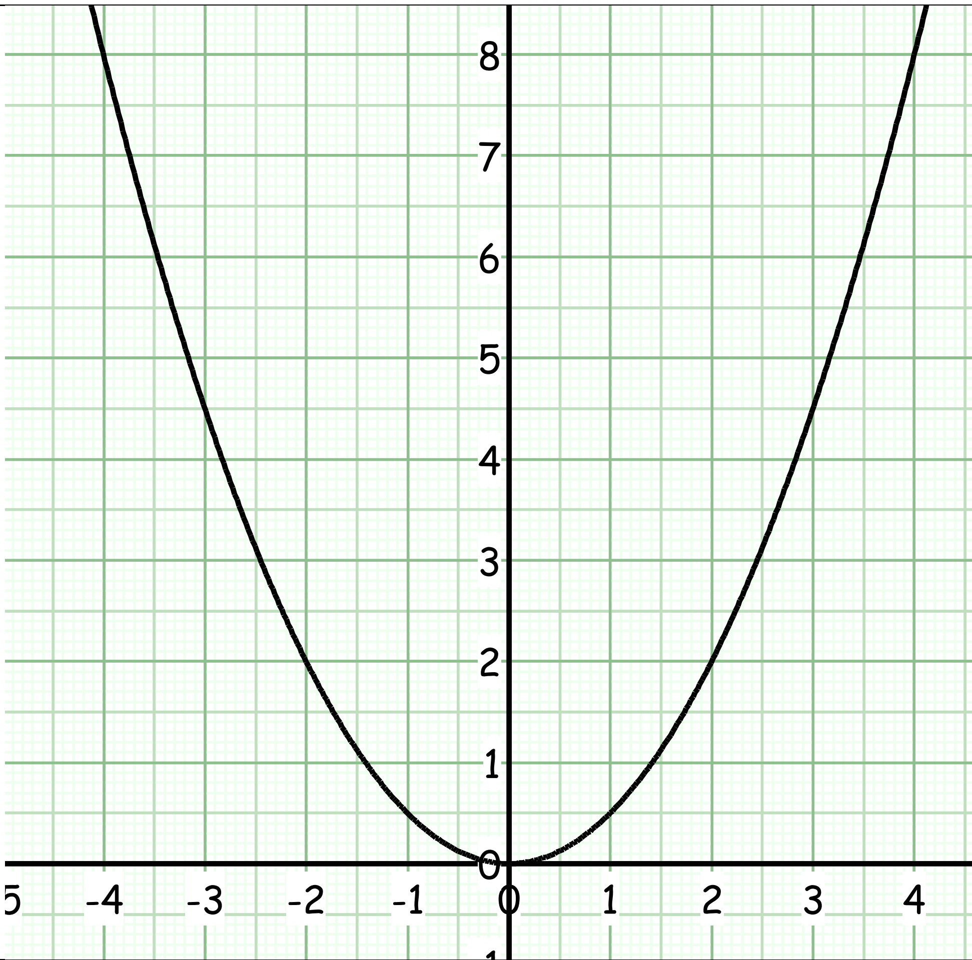
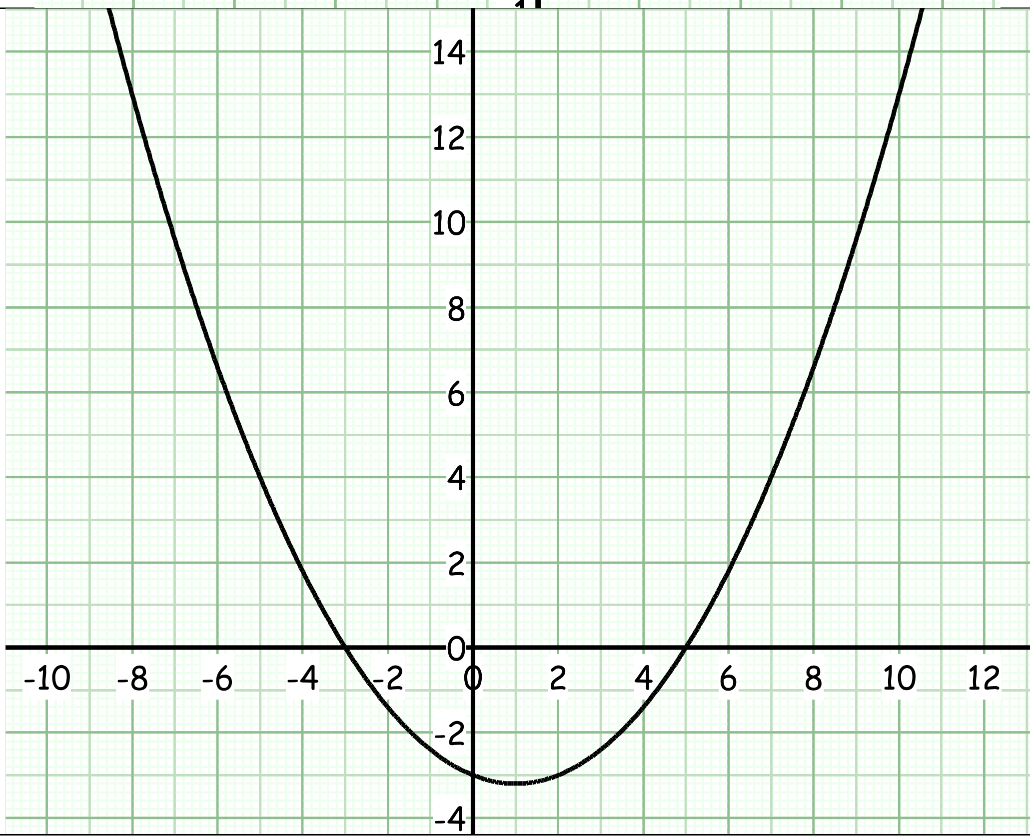
3. A student prepares a sample of the ester ethyl ethanoate by reacting ethanol and ethanoic acid.
$C_2H_5OH + CH_3COOH \rightarrow CH_3COOC_2H_5 + H_2O$

The molar mass of ethyl ethanoate = 88.0 g mol^{-1}, water = 18.0 mol^{-1}. Determine the % atom economy of this reaction. Give your answer to three significant figures.

4. A chemist prepares a sample of propan-1-ol by reacting 1-chloropropane with sodium hydroxide solution.
$CH_3CH_2CH_2Cl + NaOH \rightarrow CH_3CH_2CH_2OH + NaCl$
Determine the % atom economy of this reaction. Give your answer to three significant figures.

5. A chemist prepares a sample of ethanol by reacting sodium hydroxide solution with bromoethane.
$CH_3CH_2Br + NaOH \rightarrow CH_3CH_2OH + NaBr$
Determine the % atom economy of this reaction. Give your answer to three significant figures.

5. Gradients of tangents

1. Gradient of tangent at a) (2, 2) .... b) (-1, 0.5) .... c) (3, 4.5) .... d) (-3.5, 6)	
2. Gradient of tangent at a) (-3, 0) .... b) (10, 13) .... c) (5, 0) .... d) (-8, 13)	

Answers to Worksheets

1c) Answers

Lead has a density of 11.34 g/cm³. How much will a cubic metre of lead weigh, in kilograms? 11,340 kg

Balsa wood has a density of 0.17 g/cm³. If I have a block that weighs 1kg, what volume does it have? 5882cm³.

Normal body temperature is about 98°F. How much is this in Celsius? 37°C

Absolute zero temperature occurs at -459.67°F. How much is this in Celsius?
-273.15°C

In 2007 the UK's carbon dioxide emission in moles was 1.226 x 10^{13}. How many metric tons does this represent? (One tonne = 1000kg) 539,440,000

How many moles of hydrogen gas are in a 3.1 m^3 sample measured at 300 kPa, which is kept at room temperature? 0.82

A 0.5 m^3 container holds 0.05 moles of O_2 at room temperature. What pressure does the gas exert on the inside of the container? 114 kPa

A cyclist accelerates from 3 m/s to 5m/s taking him 10 seconds to do so. What is his acceleration? 0.2 m/s^2

A F1 car accelerates in a straight line for 200m, which takes 4 seconds. If it's initial speed was 30 m/s how fast was it travelling at the end of the straight? 70 m/s

A ball is dropped from the leaning tower of Pisa, at a height of 50m from the ground. The ball is dropped from rest and falls freely under gravity. How long will it be before the ball hits the ground? (Gravity causes acceleration of 9.8 m/s^2) 3.19s

2a) Avogadro constant Answers

1 a 6.023 x 10^{23}
b 6.023 x 10^{23}
c 6.02 3 x 10^{23}

2 a 6.02 3 x 10^{22}
b 1.51 3 x 10^{24}
c 4.52 3 x 10^{24}

3 a 6.02 3 x 10^{23}
b 6.02 3 x 10^{23}
c 6.02 3 x 10^{23}

4 a 1.204 3 x 10^{24}
b 9.03 3 x 10^{23}
c 1.204 3 x 10^{23}

5 1.204 3 x 10^{24}

6 mol = mass/Mr

Mass (g)	=	mol x Mr
	=	49 x 1/6.023 x 10^{23}
	=	8.135 x 10^{-23}
mass (kg)	=	8.135 x 10^{-26}

4a) Percentage yields answers

1 67.2%
2 91.7%
3 52.1%
4 80%
5 40%
6 20%

Atom economy Answers

1 100%
2 100%
3 83.0%
4 50.6%
5 30.9%

5 Gradient Answers