Sir John Cass & Red Coat
Sir John Cass's Foundation & Red Coat Sixth Form
www.sjcr6thform.net

Step Up to **CHEMISTRY** A Level at Sir John Cass & Red Coat

A guide for Year 11 pupils to help you get ready for A-level Chemistry at Sir John Cass 6TH Form College, including everything from topic guides to online learning resources.

"Chemistry begins in the stars. The stars are the source of the chemical elements, which are the building blocks of matter and the core of our subject."

PETER ATKINS, 1940 TO PRESENT

Booklet 2

We will achieve excellence and inspire generations the Cass Way

WE LEARN TOGETHER   WE PRAY TOGETHER   WE ACHIEVE TOGETHER

Pre-Knowledge Topics: How can you prepare for A Level Chemistry

A level Chemistry will use your knowledge from GCSE and build on this to help you understand new and more demanding ideas. Complete the following tasks to make sure your knowledge is up to date and you are ready to start studying:

Essential Mathematical Skills

At least **20%** of the marks across the question papers in A Level Chemistry will assess Mathematical skills aimed to at least the standard of higher tier GCSE mathematics. The OCR exam board has a detailed Mathematical Skills Handbook (Web link for the updated Version (1.1 – June 2019): https://www.ocr.org.uk/Images/295468-chemistry-mathematical-skills-handbook.pdf). We strongly recommend you spend some time familiarising yourself with the concepts and examples included, to prepare yourself for this course. Some of the common areas that students struggle with are outlined below.

These tasks cover work for **three weeks.** *Make a plan to spread these tasks out over this period.*

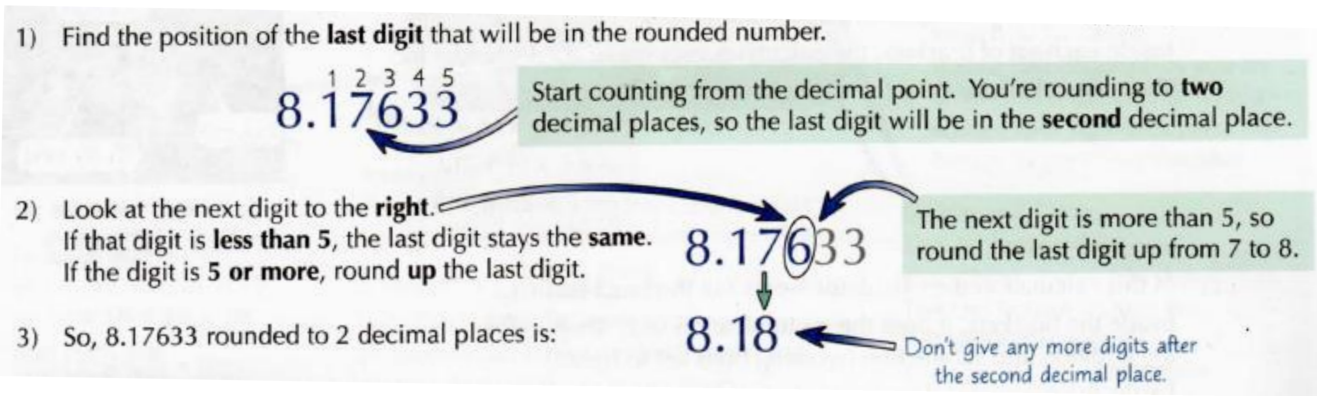
Task 1: Rounding and Decimal Places

You can **round** long decimals to a set number of decimal places.
For example, the number of moles in a 244.4g sample of magnesium sulfide is found by the calculation: number of moles = mass ÷ M_r = 244.4 ÷ 56.4 (56.4 = M_r of magnesium sulfide)

244.4 ÷56.4 = 4.33333333333333333333333333…. mol
(As the digits go further to the right, they get smaller in value)

The answer rounded to **ten** digits after the decimal place is: 4.3333333333 mol
The answer rounded to **five** digits after the decimal place is: 4.33333 mol
The answer rounded to **two** digits after the decimal place is: 4.33 mol

Rounding to a certain number of **Decimal Places**
There are certain calculations where the usual practice is to round your answer to a given number of decimal places. For example, rounding 8.17633 to 2 decimal places:



Essential Mathematical Skills

Worked Example 1

The pH of a solution is calculated to be 1.049843.
What is the pH to 3 decimal places?

1. ***Find the position of the last digit that will be in the rounded number.***
Start counting from the decimal point.
The last digit will be in the third decimal place.

1 2 3
1.049843

The last digit is 9.

2. ***Look at the next digit to the right.***
Rounding up a 9 is slightly trickier — the 9 becomes a 0, and the digit to the left of it increases by 1.

The next digit is 8.

1.049843

8 is more than 5, so round up. The last digit is 9, so 49 gets rounded up to 50.

1.049843 = **1.050 (3 d.p.)**

It's helpful to let anyone reading your answer know how you've rounded it — d.p. stands for decimal places.

Avoid Rounding Too Early

If you are doing a calculation with several steps, you should always write out your working. Whenever possible, keep the exact result of each step in your calculator to use in the next step, instead of using a rounded value. Do not round until the very end of the calculation.

Worked Example 2

A reaction produced 8.25 g of carbon dioxide (M_r = 44.0) in 23 seconds.
Find the rate of reaction in mol min^{-1} to 3 decimal places. Show your working.

number of moles = mass ÷ M_r

1. ***Convert the mass to moles.***
The number of moles is mass ÷ M_r.

8.25 ÷ 44.0
0.1875

This is an exact decimal, so don't round it — just write it down to use later in the calculation.

number of moles = 8.25 ÷ 44.0
= 0.1875

2. ***Convert the time to minutes.***
Divide by 60 to convert seconds to minutes.

23 ÷ 60
3.833333333

time in minutes = 23 ÷ 60
= 0.3833...

You can't write out the full decimal here because it goes on forever — but these dots show whoever's looking at your working that you haven't rounded yet.

3. ***Find the rate.***
The rate is 'number of moles ÷ time'.
Use the calculator's 'Ans' key to divide 0.1875 by the unrounded answer from step 2.

0.1875 ÷ Ans
0.4891304348

rate = 0.1875 ÷ 0.3833...
= 0.48913... mol min^{-1}

4. ***Find the position of the last digit that will be in the rounded number.***
Start counting from the decimal point.
The last digit will be in the third decimal place.

1 2 3
0.4891304348

The last digit is 9.

5. ***Look at the next digit to the right.***

The next digit is 1.

0.4891304348

1 is less than 5, so the last digit stays the same.

rate = 0.48913... mol min^{-1}
= **0.489 mol min^{-1} (3 d.p.)**

If you'd rounded too early and done 0.188 ÷ 0.383, you'd have ended up with 0.491 mol min^{-1} as your final answer.

Essential Mathematical Skills

Significant Figures

A **significant figure** is any digit in a value that you are confident is correct. A non-significant figure is any digit that you cannot be sure about. It is important to know how to recognise **how many** significant figures a value you are given has and how to **round** your own data to an appropriate number of significant figures.

You should **always** give your answers to an appropriate number of significant figures (unless you are using an exact value or the question instructs you otherwise).

To find the number of **significant figures** (or **s.f.**) a value is given to:

1) **Start** counting at the **first non-zero digit**.
2) **Stop** counting at the **last non-zero digit**, or the last digit after the decimal point if there are any.

So:

187.23 s is given to **5 s.f.**

9.005 kJ is given to **4 s.f.**

700 007 cm^3 is given to **6 s.f.**

448 000 g is given to **3 s.f.** (Actually, this could be to 4, 5 or 6 s.f. – but unless you know that for certain, you can only assume it is given to 3 s.f.)

Zeros that come after a decimal point give you extra information:

159.0 g is given to **4 s.f.** Using 159 g would give you the same answer in any calculation as 159.0 g, so its inclusion means it must be **significant**.

1590 g is given to **3 s.f**. However, this final zero **does not** tell you anything about how many s.f. the measurement has. You cannot tell if the mass was measured as 1590 g to **4 s.f.**, or as, say, 1592 g and then **rounded** down to 1590 g to **3 s.f.** You can only be **certain** that it has the **smaller number** of s.f., so you would assume it was given to **3 s.f.**

This is why you should always give the number of s.f. your value was measured to, e.g. 1350 cm^3 (**to 4.s.f.**)

Zeros at the start of a number are not significant:

0.039 m is given to **2** s.f.

0.000701 g is given to **3** s.f.

This makes sense if you think about converting the same number into **different units**.

0.039 m is the same as 3.9 cm or 0.000030 km – these are all **different ways** of writing the **same information**, so they must all have the same number of **s.f.**

Essential Mathematical Skills

Important **rule** for significant figures in **calculations**:

You should round your final answer to a calculation to the **same number of significant figures** as the data value with the **fewest** significant figures used in the calculation.

a) If you give an answer to **more** significant figures than the data you have used to calculate it, you are saying that your calculated result is **more precise** than the data it came from. You should therefore stick to using the smallest number of significant figures from your data.
b) The exception to this rule is when you are working with **logarithms** – they have their own rules.

It is good practice to write down the **unrounded answer** in your working, then give the **rounded answer** along with the **number of significant figures** you are giving it to. (*If you use your answer in another calculation, use the unrounded version*).

Practice Questions

Q1 Write down the following amounts:

a) 0.0272 g s^{-1} to 3 decimal places
b) 11.325 dm^3 to 2 decimal places
c) 23.976 KJ to 1 decimal place
d) 0.9191 V to 2 decimal places

Q2 A certain chemical reaction has one product, which is produced at a rate of 325g every 80 minutes. Using the formula 'rate = mass ÷ time', find the rate of this reaction in kg $hour^{-1}$. Give your answer to 2 decimal places.

Q3 A reaction was found to have a theoretical yield of 7.65g. The actual yield was 4.2g. Calculate the percentage yield of the reaction.

Q4 How many significant figures are each of these values given to?

a) 221 985 Pa
b) 15 200 g
c) 39.00 K
d) 0.00186 mol

Q5 What is 649.352 kJ to:

a) two significant figures
b) three significant figures
c) four significant figures

Q6 0.175 moles of sodium chloride were dissolved in 1.2 dm^3 of water. Using the formula, 'concentration (mol dm^{-3}) = number of moles ÷ volume (dm^3)', calculate the concentration of the resulting solution. Give your answer to an appropriate number of significant figures.

Indices (Powers) Rules:
At A Level, rather than write mol/dm^3 to mean mols per decimetre cubed, we write mol dm^{-3}.

Power or index number

$$a^2$$

Base

2^4 is a short way of writing **2** x **2** x **2** x **2**

$\boldsymbol{a} \times \boldsymbol{a} \times \boldsymbol{a} \times \boldsymbol{a} \times \boldsymbol{a} = \boldsymbol{a}^5$

To **multiply** together two identical values or variables (letters) that are presented in index form, add the powers.

$\boldsymbol{b}^5 \times \boldsymbol{b}^3 = \boldsymbol{b}^8$

In general: $\boldsymbol{a}^m \times \boldsymbol{a}^n = \boldsymbol{a}^{(m+n)}$

However, $\boldsymbol{d}^3 \times \boldsymbol{e}^2$ cannot be simplified because ***d*** and ***e*** are different.

To **divide** two identical values or variables (letters) that are presented in index form, subtract the powers.

$\mathbf{2}^5 \div \mathbf{2}^3 = \mathbf{2}^2$

In general: $\boldsymbol{a}^m \div \boldsymbol{a}^n = \boldsymbol{a}^{(m-n)}$

To raise a value or variable (letter) presented in index form to another index, **multiply** the powers together.

$(\boldsymbol{k}^3)^2 = \boldsymbol{k}^6$

In general: $(\boldsymbol{a}^m)^n = \boldsymbol{a}^{(m \times n)}$

More rules: any letter or number to the **power of 1** is the same letter or number

$\boldsymbol{k}^1 = \boldsymbol{k}$, $\quad 89^1 = 89$

Any letter or number to the **power of zero** is equal to 1

$\boldsymbol{k}^0 = 1$, $\quad 89^0 = 1$

A negative power is the same as a fraction that is '1 over the positive version of the power':

$$\boldsymbol{a^{-n} = \frac{1}{a^n}}$$

It is important to note that a common misconception is that there is a law for $\boldsymbol{a}^m + \boldsymbol{a}^n$. In general, there is no way to simplify this expression.

Practice Questions

Q1 Simplify the following expressions:

a) q^2 x q^3

b) q^5 x q^3

c) $q^3 \div q^2$

d) $q^{10} \div q^8$

Q2 Simplify the following expression:

$$\frac{x^{10}}{x^7}x^3$$

Q3 Simplify the following expressions:

a) $(q^2)^2$

b) $(3q^3)^3$

(c) $(4q2$ x $2q^2)^2$

Q4 Evaluate the following powers:

a) 100102^0

b) 1^{30}

Q5 Calculate the following:

a. $\left(\frac{1}{2}\right)^2$

b. $\left(\frac{3}{4}\right)^3$

c. $\left(1\frac{1}{2}\right)^3$

d. $\left(2\frac{4}{5}\right)^2$

Q6 Calculate the following:

a. $16^{\frac{1}{2}}$

b. $9^{\frac{1}{2}}$

c. $27^{\frac{1}{3}}$

d. $64^{\frac{1}{3}}$

e. $16^{\frac{1}{4}}$

Q7 Simplify the following:

a. $25^{-\frac{1}{2}}$

b. 4^{-2}

c. $64^{-\frac{1}{3}}$

d. $64^{-\frac{2}{3}}$

Q8 Simplify the following:

$(3x^2y^3z^4)^3$

Q9 1 mole of hydrogen ions contains 6.02×10^{23} ions. How many hydrogen ions are there in 1 dm^3 of a solution which has a hydrogen ion concentration of 1.25×10^{-4} mol dm^{-3}?

Q10 Given that 1 mole of silicon contains 6.021×10^{23} ions, find the number of atoms in 10^5 moles of silicon. Give your answer in standard form.

Q11 The equilibrium constant, K_c, for a reaction $2CH_{4(g)} \rightleftharpoons 3H_{2(g)} + C_2H_{2(g)}$ is given by the formula

$$K_c = \frac{[H_2]^3[C_2H_2]}{[CH_4]^2}$$

Square brackets, [ ], are shorthand for 'concentration of'

Calculate the **value** of K_c if $[H_2]$ = 0.60 mol dm^{-3}, $[C_2H_2]$ = 0.20 mol dm^{-3} and $[CH_4]$ = 0.40 mol dm^{-3}. Give the **units** for K_c.

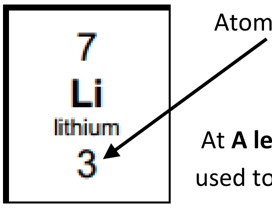
Task 2: Pre-Knowledge Topics

Chemistry Topic 1 – Electronic structure, how electrons are arranged around the nucleus

A periodic table can give you the proton / atomic number of an element, this also tells you how many electrons are in the ***atom***.

You will have used the rule of electrons shell filling, where:

The first shell holds up to 2 electrons, the second up to 8, the third up to 8 and the fourth up to 18 (or you may have been told 8).



Atomic number =3, electrons = 3, arrangement 2 in the first shell and 1 in the second or

Li = 2,1

At **A level** you will learn that the electron structure is more complex than this, and can be used to explain a lot of the chemical properties of elements.

The 'shells' can be broken down into 'orbitals', which are given letters:'s' orbitals, 'p' orbitals and 'd' orbitals.

You can read about orbitals here:

http://bit.ly/pixlchem1

http://www.chemguide.co.uk/atoms/properties/atomorbs.html#top

Now that you are familiar with s, p and d orbitals try these problems, write your answer in the format:

$1s^2$, $2s^2$, $2p^6$ etc.

Q1.1 Write out the electron configuration of:

a) Ca b) Al c) S d) Cl e) Ar f) Fe g) V h) Ni i) Cu j) Zn k) As

Q1.2 Extension question, can you write out the electron arrangement of the following ***ions***:

a) K^+ b) O^{2-} c) Zn^{2+} d) V^{5+} e) Co^{2+}

Chemistry Topic 2 – Oxidation and reduction

At GCSE you know that oxidation is adding oxygen to an atom or molecule and that reduction is removing oxygen, or that oxidation is removing hydrogen and reduction is adding hydrogen. You may have also learned that oxidation is removing electrons and reduction is adding electrons.

At A level we use the idea of ***oxidation number*** a lot!

You know that the metals in group 1 react to form ions that are +1, i.e. Na^+ and that group 7, the halogens, form -1 ions, i.e. Br -.

We say that sodium, when it has reacted has an oxidation number of +1 and that bromide has an oxidation number of -1.

All atoms that are involved in a reaction can be given an oxidation number.

An element, Na or O_2 is always given an oxidation state of zero (0), any element that has reacted has an oxidation state of + or -.

As removing electrons is **reduction**, if, in a reaction the element becomes **more** negative it has been reduced, if it becomes more positive it has been oxidised.

-5 0 +5

You can read about the rules for assigning oxidation numbers here:

http://www.dummies.com/how-to/content/rules-for-assigning-oxidation-numbers-to-elements.html

Elements that you expect to have a specific oxidation state actually have different states, so for example you would expect chlorine to be -1, it can have many oxidation states: NaClO, in this compound it has an oxidation state of +1

There are a few simple rules to remember:

Metals have a + oxidation state when they react.

Oxygen is 'king' it always has an oxidation state of -2 (there are exceptions, e.g. in H_2O_2 where it has an oxidation state of -1)

Hydrogen has an oxidation state of +1 (except metal hydrides)

The charges in a molecule must cancel.

Examples: Sodium nitrate, $NaNO_3$			sulfate ion, SO_4^{2-}	
	Na +1	3x O^{2-}	4xO^{2-}	and 2- charges 'showing'
	+1	-6	-8	-2
To cancel:	N = +5		S = +6	

Q2.1 Work out the oxidation state of the **<u>underlined</u>** atom in the following:

a) $Mg\underline{C}O_3$ b) $\underline{S}O_3$ c) $Na\underline{Cl}O_3$ d) $\underline{Mn}O_2$ e) $\underline{Fe_2}O_3$ f) $\underline{V_2}O_5$

g) $K\underline{Mn}O_4$ h) $\underline{Cr_2}O_7^{2-}$ i) $\underline{Cl_2}O_4$

Chemistry Topic 3 – Isotopes and mass

You will remember that isotopes are atoms of the same element that have differing numbers of neutrons. Hydrogen has 3 isotopes: Protium H_1^1 Deutrium H_1^2 Tritium H_1^3

Isotopes occur naturally, so in a sample of an element you will have a mixture of these isotopes. We can accurately measure the amount of an isotope using a **mass spectrometer**. You will need to understand what a mass spectrometer is and how it works at A level ('Time of Flight' type).

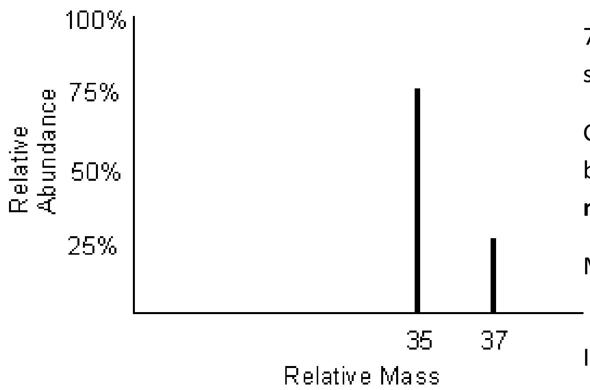
You can read about a mass spectrometer here:

http://bit.ly/pixlchem3
http://www.kore.co.uk/tutorial.htm
http://bit.ly/pixlchem4
http://filestore.aqa.org.uk/resources/chemistry/AQA-7404-7405-TN-MASS-SPECTROMETRY.PDF

Q3.1 What must happen to the atoms before they are accelerated in the mass spectrometer?

Q3.2 Explain why the different isotopes travel at different speeds in a mass spectrometer.

A mass spectrum for the element chlorine will give a spectrum like this:



75% of the sample consist of chlorine-35, and 25% of the sample is chlorine-37.

Given a sample of naturally occurring chlorine ¾ of it will be Cl-35 and ¼ of it is Cl-37. We can calculate what the **mean** mass of the sample will be:

$$\text{Mean mass} = \frac{75 \times 35}{100} + \frac{25 \times 37}{100} = 35.5$$

If you look at a periodic table this is why chlorine has an atomic mass of 35.5.

http://www.avogadro.co.uk/definitions/ar.htm

An A level periodic table has the masses of elements recorded much more accurately than at GCSE. Most elements have isotopes and these have been recorded using mass spectrometers.

GCSE

11 **B** boron 5	12 **C** carbon 6	14 **N** nitrogen 7	16 **O** oxygen 8	19 **F** fluorine 9
27 **Al** aluminium 13	28 **Si** silicon 14	31 **P** phosphorus 15	32 **S** sulfur 16	35.5 **Cl** chlorine 17

A level

10.8 **B** 5 boron	12.0 **C** 6 carbon	14.0 **N** 7 nitrogen	16.0 **O** 8 oxygen	19.0 **F** 9 fluorine
27.0 **Al** 13 aluminium	28.1 **Si** 14 silicon	31.0 **P** 15 phosphorus	32.1 **S** 16 sulphur	35.5 **Cl** 17 chlorine

Given the percentage of each isotope you can calculate the mean mass which is the accurate atomic mass for that element.

Q3.3 Use the percentages of each isotope to calculate the accurate atomic mass of the following elements.

a) Antimony has 2 isotopes: Sb-121 57.25% and Sb-123 42.75%
b) Gallium has 2 isotopes: Ga-69 60.2% and Ga-71 39.8%
c) Silver has 2 isotopes: Ag-107 51.35% and Ag-109 48.65%
d) Thallium has 2 isotopes: Tl-203 29.5% and Tl-205 70.5%
e) Strontium has **4** isotopes: Sr-84 0.56%, Sr-86 9.86%, Sr-87 7.02% and Sr-88 82.56%

Essential Mathematical Skills Answers

Rounding, decimal place and significant figures

Q1 a) 0.027 g s^{-1} b) 11.33 dm^3 c) 24.0 KJ d) 0.92 V

Q2 325g = (325 ÷1000) kg = 0.325 kg

80 minutes = (80 ÷ 60) hours = 1.333…. hours

So the rate = 0.325 ÷ 1.333…

= 0.24375 kg $hour^{-1}$

= **0.24 kg $hour^{-1}$ (2 d.p.)**

Alternative calculation: 80 minutes = 1 1/3 hours, or 4/3 hours

So the rate = 0.325 ÷ 4/3

= 0.325 x ¾

= 0.24375 kg $hour^{-1}$

= **0.24 kg $hour^{-1}$ (2 d.p.)**

Q3 Percentage yield = actual yield/theoretical yield x 100%

4.2/7.65 x 100% = 54.90196078…. Do not round answer yet

The actual yield is 4.2g, si it is given to 2 s.f., and the theoretical yield is 7.65g, so it is given to 3 s.f.

The actual yield has the fewest significant figures (2) so the final answer should also be given to 2 significant figures. = **55% (to 2 s.f.)**

Q4 a) 6 b) 3 (This could have 4 or 5 significant figures – but you can only say for sure that it has 3 c) 4 d) 3

Q5 a) 650 kJ b) 649 kJ c) 649.4 kJ

Q6 0.175 ÷ 1.2 = 0.145833… mol dm^{-3}

= **0.15 mol dm^{-3} (to 2 s.f.)**

The volume of water (1.2 dm^3) is the data value with the fewest number of significant figures in this calculation – it is given to two significant figures, so you should round the final answer to two significant figures too.

Indices (Powers) Rules

Q1 a) q^5 b) q^8 c) q d) q^2

Q2 X^6

Q3 a) $\boldsymbol{q}^4$ b) $27\boldsymbol{q}^9$ c) $64\boldsymbol{q}^8$

Q4 a) 1 b) 1

Q5 a) $\frac{1}{4}$ b) $\frac{27}{64}$ c) $\frac{27}{8}$ d) $\frac{196}{25}$

Q6 a) 4 b) 3 c) 3 d) 4 e) 2

Q7 a) $\frac{1}{5}$ b) $\frac{1}{16}$ c) $\frac{1}{4}$ d) $\frac{1}{16}$

Q8 $27\boldsymbol{x}^6\boldsymbol{y}^9\boldsymbol{z}^{12}$

Q9 7.53×10^{19} ions (3 s.f.)

Q10 $6.02 \times 10^{23} \times 10^5 = 6.02 \times 10^{23+5}$

$= \mathbf{6.02 \times 10^{28}}$

Q11 $K_c = (0.60^3 \times 0.20) \div 0.40^2 = (0.216 \times 0.20) \div 0.16$

$= \mathbf{0.27\ mol^2\ dm^{-6}}$

Pre-Knowledge Topics Answers to problems

Q1.1a) $1s^2\ 2s^2\ 2p^6 3s^2 3p^6 4s^2$ b) $1s^2\ 2s^2\ 2p^6 3s^2 3p^1$ c) $1s^2\ 2s^2\ 2p^6 3s^2 3p^4$ d) $1s^2\ 2s^2\ 2p^6 3s^2 3p^5$

e) $1s^2\ 2s^2\ 2p^6 3s^2 3p^6$ f) $1s^2\ 2s^2\ 2p^6 3s^2 3p^6\ 3d^6 4s^2$ g) $1s^2\ 2s^2\ 2p^6 3s^2 3p^6\ 3d^3 4s^2$

h) $1s^2\ 2s^2\ 2p^6 3s^2 3p^6\ 3d^8 4s^2$ i) $1s^2\ 2s^2\ 2p^6 3s^2 3p^6\ 3d^{10}\ 4s^1$ j) $1s^2\ 2s^2\ 2p^6 3s^2 3p^6\ 3d^{10}\ 4s^2$

k) $1s^2\ 2s^2\ 2p^6 3s^2 3p^6\ 4s^2\ 3d^{10}\ 4p^3$

Q1.2a) $1s^2\ 2s^2\ 2p^6 3s^2 3p^6$ b) $1s^2\ 2s^2\ 2p^6 3s^2 3p^6$ c) $1s^2\ 2s^2\ 2p^6 3s^2 3p^6\ 3d^{10}$

d) $1s^2\ 2s^2\ 2p^6 3s^2 3p^6$ e) $1s^2\ 2s^2\ 2p^6 3s^2 3p^6\ 3d^7$

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Q2.1 a) +4 b) +6 c) +5 d) +4 e) +3 f) +5 g) +7 h) +6 i) +4

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Q3.1 They must be ionised / turned into ions

Q3.2 The ions are all given the same amount of kinetic energy, as KE = ½ mv^2 the lighter ions will have greater speed / heavier ions will have less speed.

Q3.3 a) 121.855 b) 67.796 c) 107.973 d) 204.41 e) 87.710 / 87.7102

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