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VCE Chemistry ½
Moles & Stoichiometry Revision [2.4]
Homework Solutions

Admin Info & Homework Outline:

Student Name	
Questions You Need Help For	
[2.1] – Moles & Molar Mass	Pg 2 – Pg 13
[2.2] – Relative Atomic Mass & Percentage Composition	Pg 14 – Pg 29
[2.3] – Stoichiometry	Pg 30 – Pg 43
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Section A: [2.1] - Moles & Molar Mass (61 Marks)

Sub-Section [2.1.1]: Apply Avogadro's Number to Mole Calculations using $n = N/N_a$

Question 1 (4 marks)

For the following questions, calculate the amount required.

a. The moles of magnesium atoms in 1.204×10^{24} particles. (1 mark)

2.00 moles

b. The particles of argon atoms in 19 moles. (1 mark)

1.144×10^{25} particles

c. The moles of francium atoms in 3.913×10^{24} particles. (1 mark)

6.5 moles

d. The particles of copper atoms in 9.654 moles. (1 mark)

5.820×10^{24} particles

Space for Personal Notes

Question 2 (4 marks)

Find the number of particles in the following.

a. In 2 moles of O_2, find the particles of oxygen atoms. (1 mark)

$2 \times 6.02 \times 10^{23} \times 2 = 2.408 \times 10^{24}$ particles of O

b. In 4 moles of $CaCl_2$, find the particles of calcium ions. (1 mark)

$4 \times 6.02 \times 10^{23} = 2.408 \times 10^{24}$ particles of calcium

c. If we knew that a sample of CO_2 contained 1.20×10^{24} particles of oxygen, how many moles of CO_2 were there? (2 marks)

$1.20 \times 10^{24} / 2 / 6.02 \times 10^{23} = 0.997$ moles

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Question 3 (6 marks)

Consider the compound of ammonia, NH_3.

a. If there are 6.02×10^{24} molecules of ammonia, how many moles of ammonia are present? (1 mark)

10 moles

b. How many nitrogen atoms are there in this amount of ammonia? (1 mark)

$6.02 \times 10^{24} \times 1 = 6.02 \times 10^{24}$ atoms of N

c. How many hydrogen atoms are there in this amount of ammonia? (1 mark)

$6.02 \times 10^{24} \times 3 = 1.806 \times 10^{25}$ atoms of hydrogen

d. Given that we have 4.518×10^{24} atoms of hydrogen in a sample of ammonia, calculate the moles of ammonia we have in total. (3 marks)

$4.518 \times 10^{24} / 3 = 1.506 \times 10^{24}$ molecules of ammonia
$1.506 \times 10^{24} / 6.02 \times 10^{23} = 2.5$ moles of ammonia

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Question 4 (6 marks)

Consider the compound of $KMnO_4$, commonly referred to as potassium permanganate.

a. Given that we have 6.41×10^{29} particles of oxygen, what number of particles of manganese and potassium do we have? (2 marks)

Manganese and potassium are both the same at 1.6025×10^{29} particles.

b. Hence, what number of moles of potassium permanganate do we have? (1 mark)

$1.6025 \times 10^{29} / 6.02 \times 10^{23} = 2.66 \times 10^{5}$ moles

c. A student says that 100 molecules of O_2 versus 100 molecules of Se_2, because Se is a much bigger molecule than O, their amount in moles will be different. Evaluate this statement. (3 marks)

This is false as moles and particles/molecules are related using $n = N/N_A$ and so we use moles as a way to group molecules together and count them more easily instead of using very large individual counting methods. Hence, as it's just used to count molecules/particles 100 molecules of both Se_2 and O_2 will be the same amount of moles. $\left(\frac{100}{6.02} \times 10^{23}\right) = 1.66 \times 10^{-22}$ moles.

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Sub-Section [2.1.2]: Apply Molar Mass to Mole Calculations Using $n = m/M$

Question 5 (4 marks)

For the following substances, find their molar mass.

a. CO_2. (1 mark)

$12 + 32 = 44\ g\ mol^{-1}$

b. KCl. (1 mark)

$39.1 + 35.5 = 74.6\ g\ mol^{-1}$

c. $CaCO_3$. (1 mark)

$40.1 + 12 + 48 = 100.1\ g\ mol^{-1}$

d. $C_6H_{12}O_6$. (1 mark)

$180\ g\ mol^{-1}$

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Question 6 (4 marks)

For the following samples, calculate the amount required.

a. Given that there is 5.0 g of CO_2, calculate the moles present. (1 mark)

$\frac{5.0}{44.0} = 0.11$ moles

b. Given that there is 10.0 g of NaOH, calculate the moles of sodium hydroxide. (1 mark)

$\frac{10.0}{40.0} = 0.250$ moles

c. Given that there are 3.00 moles of $MgCl_2$, calculate the mass present. (1 mark)

$3.00 \times 95.3 = 286\ g$

d. Given that there are 2.50 moles of KNO_3, calculate the mass present. (1 mark)

$2.50 \times 101.1 = 253\ g$

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Question 7 (5 marks)

a. Given that a sample contains 12.50 moles and weighs 778.75 g, what is its molar mass? (2 marks)

$778.75 / 12.50 = 62.3\ g\ mol^{-1}$

b. Based on your understanding of molar mass, is it reasonable to assume that 10 g of $NaNO_3$ will be similar in amount to 10 g of $CsNO_3$? Explain. (3 marks)

No, because the molar mass of $NaNO_3$ is 85 $g\ mol^{-1}$ whereas $CsNO_3$ is 195 $g\ mol^{-1}$ which means their respective mole amounts would be 0.117 vs 0.0513, which means that there is double the amount of $NaNO_3$ compared to $CsNO_3$.

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Question 8 (7 marks)

Consider an unknown chemical X_2O. We know that there are 7.89×10^{25} atoms of oxygen in this sample.

a. What is the number of individual atoms in our sample? (2 marks)

$7.89 \times 10^{25} \times 3 = 2.367 \times 10^{26}$ atoms

b. Find the moles of X_2O. (2 marks)

$7.89 \times 10^{25} \,/\, 6.02 \times 10^{23} \;=\; 131.06$ moles

c. If the compound is 12345 grams, find its molar mass. (2 marks)

$12345 \,/\, 131.06 \;=\; 94.2\ g\ mol^{-1}$

d. What is X's identity? (1 mark)

$94.2 - 16 \;=\; 78.2 \,/2 \;= 39.1$ (POTASSIUM)

Space for Personal Notes

Sub-Section [2.1.3]: Apply Unit Conversions to Calculation Questions

Question 9 (4 marks)

For the following, convert the current units to the units required.

a. Convert 5.50 kg to grams. (1 mark)

5500 grams

b. Convert 3 hours to seconds. (1 mark)

10800 seconds

c. Convert 7500 milligrams to kilograms. (1 mark)

$7.5 \times 10^{-3}\ kg$

d. Convert 25 micrometres to metres. (1 mark)

$2.5 \times 10^{-5}\ m$

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Question 10 (4 marks)

Find the missing value for the following scenarios.

a. Given that a sample of K_2SO_4 weighed 2.50 kg, what is the number of moles present? (1 mark)

$2.50 = 2500\ g, 2500 / 174 = 14.37$ moles

b. Given that another sample of $CaCl_2$ weighed 980 mg, what is the number of atoms of chlorine present? (3 marks)

$980\ mg = 0.98\ g$
$0.98 / 111 = 0.00883$ moles
$0.08833 \times 6.02 \times 10^{23} \times 2 = 1.06 \times 10^{22}$ atoms of chlorine

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Question 11 (5 marks)

Consider the compound of calcium bromide.

a. What is its molar mass? (1 mark)

$40.1 + 79.9 + 79.9 = 199.9$

b. Given that, a sample contains 9.7412×10^{-4} megagrams, what is the number of moles present? (2 marks)

$974.12\ g$
$974.12 / 199.9 = 4.87$ moles

c. Now, given that is the case, find the mass of bromine in the sample, expressed in milligrams. (2 marks)

$4.87 \text{ moles} \times 2 = 9.74$ moles of bromine
$9.74 \times 79.9 = 778.226$ grams of bromine $= 7.78 \times 10^5\ mg$

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Question 12 (8 marks)

Consider a molecule of $K_2Cr_2O_7$, commonly referred to as potassium dichromate.

a. What is the molar mass of this molecule? (1 mark)

$39.1 \times 2 + 2 \times 52 + 16 \times 7 \ = \ 294.2 \ g \ mol^{-1}$

b. What type of intramolecular bonding holds this molecule together? (1 mark)

Ionic bonding

c. If there was 20.3 mg of potassium dichromate present, how many moles of it are present? (1 mark)

$20.3 \times 10^{-3} \ / \ 294.2 \ = \ 6.90 \times 10^{-5}$ moles

d. From your previous answer, calculate the number of molecules of potassium dichromate present. (2 marks)

$6.90 \times 10^{-5} \times 6.02 \times 10^{23} = 4.15 \times 10^{19}$ molecules

e. Now, state how many kilograms of oxygen was present in the sample. (3 marks)

$4.15 \times 10^{19} \times 7 = 2.908 \times 10^{20}$ atoms of oxygen / $6.02 \times 10^{23} \ = \ 4.826 \times 10^{-4}$ moles of oxygen $\times 16 \ = \ 7.721 \times 10^{-3}$ grams of oxygen $= 7.72 \times 10^{-6} \ kg$

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Section B: [2.2] – Relative Atomic Mass & Percentage Composition (83 Marks)

Sub-Section [2.2.1]: Calculate The Percentage Composition By Mass Of An Element In A Compound

Question 13 (4 marks)

For the following, find the percentage composition of the required element in the substance.

a. Oxygen in H_2O_2. (1 mark)

Molar mass $= 2 + 32 = 34$
$32 / 34 \times 100 = 94.11\%$

b. Carbon in CO_2. (1 mark)

Molar mass $= 44$
$12/44 \times 100 = 27.27\%$

c. Hydrogen in NH_3. (1 mark)

$3/17 \times 100 = 17.64\%$

d. Sulphur in SO_3. (1 mark)

$32.1 + 48 = 80.1$
$32.1/80.1 \times 100 = 40.07\%$

Question 14 (2 marks)

For the following, find the percentage composition of the required element in the substance.

a. Phosphorus in H_2PO_4. (1 mark)

Molar mass $= 2 + 31 + (16 \times 4) = 97$
$31 / 97 \times 100 = 31.96\%$

b. Magnesium in $Mg_3(PO_4)_2$. (1 mark)

Molar mass $= 24.3 \times 3 + (31 \times 2) + 16 \times 8 = 262.9$
$24.3 \times 3 \,/\, 262.9 \times 100 = 27.73\%$

Question 15 (4 marks)

For the following, find the percentage composition of all the elements in the compound.

a. $Ca(ClO_4)_2$. (2 marks)

Molar mass $= 40.1 + (35.5 \times 2) + (8 \times 16) = 239.1$
Ca $= 16.77\%$
Cl $= 29.70\%$
O $= 53.53\%$

b. $KHSO_3$. (2 marks)

Molar mass = 39.1 + 1 + 32.1 + 48 = 120.2
K = 32.53%
H = 0.83%
S = 26.71%
O = 39.93%

Question 16 (8 marks)

Consider the molecule of C_3H_7OH.

a. What is the percentage composition by mass of carbon? (2 marks)

Molar mass = 60
$36/60 \times 100 = 60\%$

b. What is the percentage composition by mass of hydrogen? (2 marks)

$8/60 \times 100 = 13.33\%$

c. Explain why the value you obtained for carbon is higher than hydrogen when the individual number of hydrogens is more than carbon. (2 marks)

This is because carbon has a higher molar mass than hydrogen and so it would contribute more to the overall mass of the compound than hydrogen, irrespective of the individual amount of atoms per molecule of C_3H_7OH.

d. Can the percentage composition be 100% for an element in a compound? (2 marks)

Only in pure elements, otherwise no.

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Sub-Section [2.2.2]: Find The Empirical Formula & Amp; Molecular Formula Of A Compound

Question 17 (3 marks)

A 3.66 g sample of iron combines with oxygen to give 5.232 g of the final product, which contains only iron and oxygen. Determine the empirical formula.

$$\text{Iron} = 3.66 / 55.8 = 0.0655$$
$$\text{Oxygen} =. 5.232 - 3.66 = 1.572 / 16 = 0.09825$$
$$\text{Ratio: } 1 : 1.5 \rightarrow Fe_2O_3$$

Question 18 (4 marks)

Find the empirical formulae given the below information.

a. A compound contains 26.2% nitrogen, 7.5% hydrogen, and 66.3% chlorine. (2 marks)

NH_4Cl

b. A compound contains 19.4% carbon, 3.2% hydrogen, 77.4% oxygen. (2 marks)

CH_2O_3

Question 19 (3 marks)

A sample of an unknown compound is found to contain 0.825 g of carbon, 0.138 g of hydrogen and 1.037 g of oxygen. If the molar mass of the compound is 120 $g\ mol^{-1}$, determine its molecular formula.

$0.825/12 = 0.0687 / 0.0648 = 1.061$
$0.138 / 1 = 0.138/0.0648 = 2.110$
$1.037 / 16 = 0.0648 / 0.0648 = 1$
$1:2:1 \rightarrow CH_2O$
Molar mass = $120\ g\ mol^{-1} \rightarrow 120 / 30 = 4 \rightarrow C_4H_8O_4$

Question 20 (7 marks)

a. A sample of an unknown compound contains 0.200 g of carbon, 0.05 g of hydrogen and 0.300 g of oxygen. Find the empirical formula. (3 marks)

$0.2 / 12 = 0.01667 / 0.01667 = 1$
$0.05 /1 = 0.05/ 0.01667 = 2.97$
$0.3 / 16 = 0.0188 / 0.01667 = 1.13$
CH_3O (Empirical formula)

b. Given that the molar mass of the compound is 90 $g\ mol^{-1}$, how many of the empirical formula is required? (1 mark)

$90/31 = 2.9 \rightarrow$ 3 times

c. As such, what is the molecular formula? (1 mark)

$C_3H_9O_3$

d. Is it possible to have two molecular formulae with the same empirical formula? Give an example. (2 marks)

Yes, for example, CH_4 and C_2H_8 are both valid molecules. Empirical formula is non-unique.

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Sub-Section [2.2.3]: Calculate the Relative Atomic Mass of a Compound From its Relative Isotopic Abundance

Question 21 (4 marks)

a. Boron exists in two isotopes, B-10 and B-11, with relative abundances of 19.9% and 80.1% respectively. Calculate the relative atomic mass of boron. (2 marks)

$(10 \times 0.199) + (11 \times 0.801) = 10.80\ g\ mol^{-1}$

b. Silver has two isotopes, Ag-107 and Ag-109, with relative abundances of 51.82% and 48.18% respectively. Calculate its relative atomic mass. (2 marks)

$107 \times 0.5182 + 109 \times 0.4818 = 107.97\ g\ mol^{-1}$

Question 22 (2 marks)

Neon has three isotopes: Ne-20, Ne-21, and Ne-22. Their relative abundances are 90.48%, 0.27% and 9.25% respectively. Find the relative atomic mass of neon.

$(20 \times 0.9048) + (21 \times 0.0027) + (22 \times 0.0925) = 20.18\ g\ mol^{-1}$

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Question 23 (4 marks)

Gallium exists as two isotopes, Ga-69 and Ga-71 with relative abundances of 60.11% and 39.89% respectively.

a. Calculate its relative atomic mass. (2 marks)

$(69 \times 0.6011) + (71 \times 0.3989) = 69.72\ g\ mol^{-1}$

b. Since Gallium has two isotopes exactly, why aren't their abundances not 50% each? (2 marks)

Because in existence, the amount of gallium-69 is more than the amount of gallium-71 that exists naturally and so we need to take that into account when calculating the relative atomic mass.

Question 24 (7 marks)

Carbon exists in two isotopes mainly, C-12 and C-13 with relative atomic abundances of 98.93% and 1.07% respectively.

a. Determine the relative atomic mass of carbon. (2 marks)

$(12 \times 0.9893) + (13 \times 0.0107) = 12.01\ g\ mol^{-1}$

b. Do you think that when we obtain a sample of carbon at random, the atomic mass of that sample is equivalent to the relative atomic mass? (2 marks)

No, because the relative atomic mass is generalised to the amount of carbon that exists naturally, but in our sample the actual amounts may differ, it's just easy to use the RAM for calculations.

c. Suppose we collected a sample of carbon-13 exclusively, should the atomic mass be the same as the relative atomic mass? Justify your answer. (3 marks)

No, it is not the same as the relative atomic mass takes into account the existence of all forms of carbon, and if we know that our sample only has carbon-13 we can at least be sure that the atomic mass of carbon in that sample is 13 $g\ mol^{-1}$.

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Sub-Section [2.2.4]: Find the Relative Isotopic Abundance from a Compound's RAM / Molar Mass

Question 25 (2 marks)

The relative atomic mass of an element Y is 63.55. If the element consists of two isotopes with masses 63 and 65, determine the percentage abundance of each isotope.

$63.55 = (x \times 63) + ((1 - x) \times 65) \rightarrow$ Y-63 $= 72.5\%$ and Y-65 $= 27.5\%$

Question 26 (3 marks)

An element Z has a relative atomic mass of 20.18 and consists of two isotopes: Z-20 and Z-22. Find the percentage abundance of each isotope and identify the element.

$20.18 = (x \times 20) + ((1 - x) \times 22)$
Z-20 $= 91.0\%$ and Z-22 $= 9.0\%$
Neon

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Question 27 (4 marks)

Iron has two main isotopes we are interested in, Fe-54 and Fe-56.

a. Determine the percentage abundance of each isotope. (2 marks)

$55.8 = (x \times 54) + ((1 - x) \times 56)$
Fe-54 = 10%
Fe-56 = 90%

b. Would this change if we were looking at Fe^{2+} or Fe^{3+}? Explain. (2 marks)

No, it wouldn't because electrons do not contribute to the mass number and hence, determination of isotope at all.

Question 28 (8 marks)

The relative atomic mass of an element Q is 10.81. It has two isotopes, Q-10 and Q-11.

a. Calculate the percentage abundances of each isotope. (2 marks)

$10.81 = (x \times 10) + ((1 - x) \times 11)$
Q-10 = 19.0% and Q-11 = 81.0%

b. Identify the element identity of element Q. (1 mark)

Boron

c. In the case of two isotopes that exist for the element Q, explain why we only need the abundance of one of the isotopes and not the other. (2 marks)

Because if there are only two, it is just a subtraction of one abundance from the total value of 100%.

d. What would you need to calculate the abundances of a compound with three main isotopes? (2 marks)

You can set it up like this:

A-1: : x

A-2: a

A-3: $1 - (x - a)$

Essentially, we need to know the relationship between 2 of the isotopes out of the three, for example, we can calculate it if we know the second isotope is twice the abundance of the first one.

e. What is the isotopic symbol for the less abundant isotope? (1 mark)

$10{,}5\ B$

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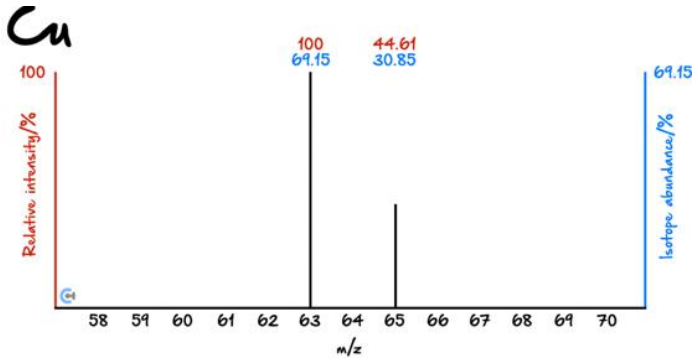
Sub-Section [2.2.5]: Apply Mass Spectrum Readings To RAM & Amp; Relative Isotopic Abundance Calculations

Question 29 (2 marks)

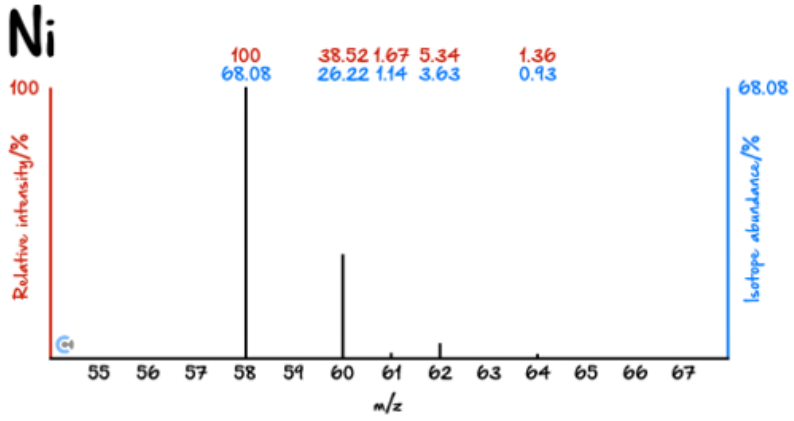
Find the relative atomic mass of Copper below.



$$0.6915 \times 63 + 0.3086 \times 65 = 63.62\ g\ mol^{-1}$$

Question 30 (2 marks)

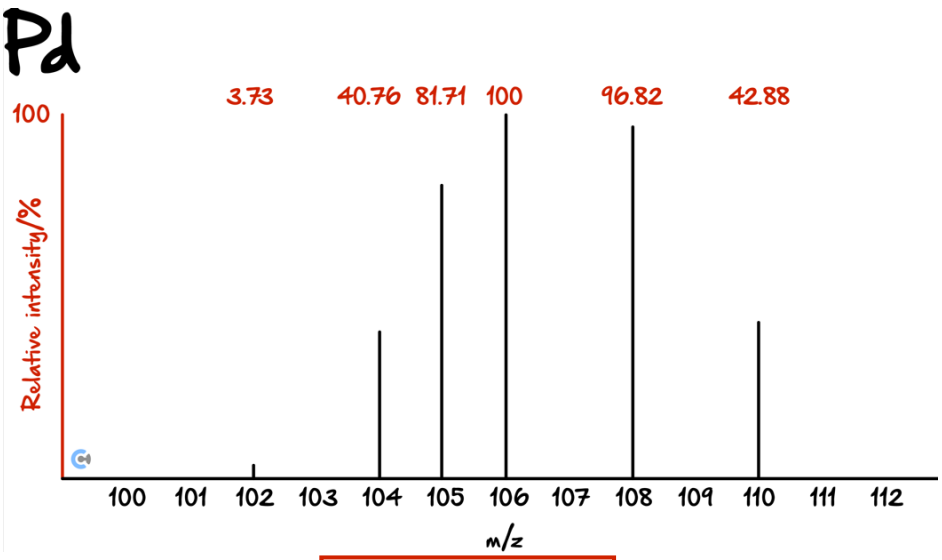
Find the relative atomic mass for Nickel given the following mass.



$$0.6808 \times 58 + 0.2622 \times 60 + 0.014 \times 61 + 0.0363 \times 62 + 0.0093 \times 64 = 58.899\ g\ mol^{-1}$$

Question 31 (3 marks)

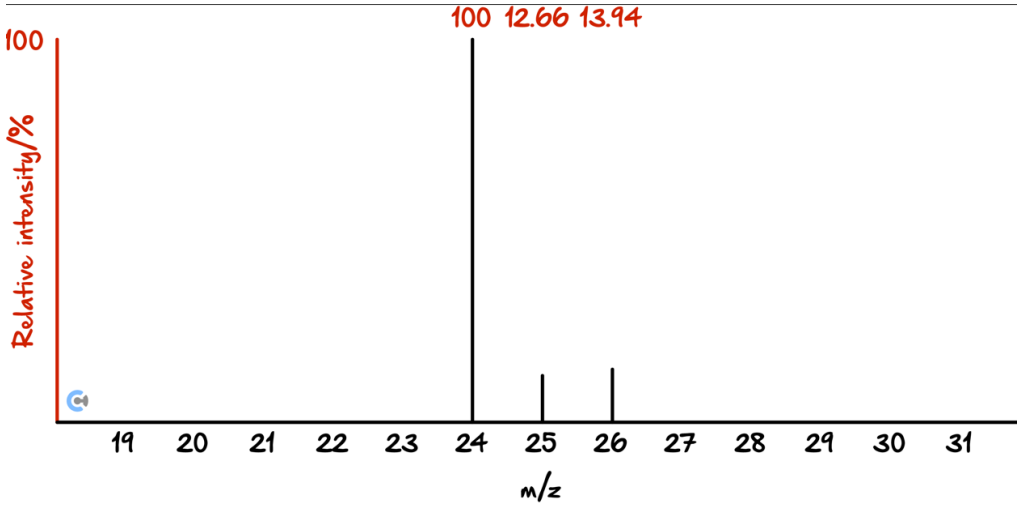
The mass spectrum of Palladium is shown below. Determine the relative atomic mass of Palladium.



$106.44\ g\ mol^{-1}$

Question 32 (7 marks)

Given the following mass spectrum.



a. Determine the relative atomic mass. (2 marks)

$24.3\ g\ mol^{-1}$

b. What is the compound most likely going to be? (1 mark)

Magnesium

c. Does it matter if the relative intensity of all recorded isotopes is above 100%? (2 marks)

No, because it's all relative to the base peak anyway and so we just calculate the new total intensity and do our calculations relative to that.

d. Would you expect the result of a mass spectrum from Mg to be different from Mg^{2+}? (2 marks)

No, because it needs to be ionised when it enters the chamber anyway. (ext: Mg^{+} actually because it knocks off one electron only, and so this might affect the curve of the ion in the spectrum).

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Section C: [2.3] – Stoichiometry (79 Marks)

Sub-Section [2.3.1]: Write Balanced Chemical Equations, Including Combustion

Question 33 (1 mark)

Balance the equation where CH_4 reacts with oxygen gas to form carbon dioxide and water.

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

Question 34 (4 marks)

Balance the following equations:

a. $KClO_3 \rightarrow KCl + O_2$. (1 mark)

$2KClO_3 \rightarrow 2KCl + 3O_2$

b. $CH_3OH + O_2 \rightarrow H_2O + CO_2$. (1 mark)

$CH_3OH + O_2 \rightarrow 2H_2O + CO_2$

c. $Ca(OH)_2 + HCl \rightarrow CaCl_2 + H_2O$. (1 mark)

$Ca(OH)_2 + 2HCl \rightarrow CaCl_2 + 2H_2O$

d. $AgCl + Mg(NO_3)_2 \rightarrow MgCl_2 + AgNO_3$. (1 mark)

$2AgCl + Mg(NO_3)_2 \rightarrow MgCl_2 + 2AgNO_3$

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Question 35 (4 marks)

Balance the following combustion equations:

a. Ethanol's complete combustion. (2 marks)

$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$

b. Decane's complete combustion. (2 marks)

$2C_{10}H_{22} + 31O_2 \rightarrow 20CO_2 + 22H_2O$

Question 36 (7 marks)

Consider the combustion equation of butanol.

a. Write the balanced equation, assuming that CO_2 and H_2O is produced. (2 marks)

$C_4H_9OH + 6O_2 \rightarrow 4CO_2 + 5H_2O$

b. Now, consider when CO and H_2O is produced. (1 mark)

$C_4H_9OH + 5O_2 \rightarrow 4CO + 5H_2O$

c. Why is it suggested that we balance carbon last in a chemical equation generally? (2 marks)

We balance carbon last because other elements can exist in isolation whereas carbon is more likely to exist with something else and so it is harder to balance since it affects multiple species, so we leave it until the end to make it easier.

d. A student argues that we can have more matter at the end of a reaction as we are inputting energy into the reaction system, as a combustion reaction usually results in our fuel disappearing over time. Evaluate this statement. (2 marks)

This is not true due to the law of conservation of mass stating that the matter that is at the start of the reaction should be present at the end of the reaction, and that matter cannot be created or destroyed, just transformed. In this case the fuel would have just transformed into energy and gas that is released into the environment and so that's why we see it as changing, but if we captured everything it would be the same amount of matter.

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Sub-Section [2.3.2]: Apply Stoichiometry to Find the Amount of Another Substance Used / Produced

Question 37 (2 marks)

Given the equation:

$$2KClO_3 \rightarrow 2KCl + 3O_2$$

If 5.50 moles of $KClO_3$ reacts, then how much oxygen gas would be produced, in moles?

$5.50 \times 3 / 2 = 8.25$ moles of oxygen gas.

Question 38 (4 marks)

Given the following equation:

$$2Al_2O_3 \rightarrow 4Al + 3O_2$$

a. If 7.00 g of Al_2O_3 decomposes, how many grams of O_2 gas would be produced? (2 marks)

$7 / (27 \times 2 + 16 \times 3) = 0.0686$ moles
$0.0686 \times 3 / 2 = 0.1029$ moles of oxygen gas $\times 32 = 3.29\ g$ of O_2 gas.

b. If 3.00 g of oxygen gas was produced how much Al_2O_3 would've been needed, in grams? (2 marks)

$3 / 32 = 0.09375 \times 2 / 3 = 0.0625$ moles of Al_2O_3
$0.0625 \times (27 \times 2) + (16 \times 3) = 6.375\ g$.

Question 39 (4 marks)

Given the combustion of 8.49 g of propanol, C_3H_7OH, calculate the total mass of gases released, assuming the reaction occurred at 120℃.

Reaction: $2C_3H_7OH + 9O_2 \rightarrow 6CO_2 + 8H_2O$
$8.49 / 60 = 0.1415$ moles
$0.1415 \times 6 / 2 = 0.4245 \times 44 = 18.68\ g$ of CO_2
$0.1415 \times 8 / 2 = 0.566$ moles of steam $\times 18 = 10.19\ g$ of Steam.

Question 40 (9 marks)

Consider the following chemical equation:

$$H_3PO_4 + KOH \rightarrow K_3PO_4 + H_2O$$

a. Balance the above equation as it is currently unbalanced. (1 mark)

$H_3PO_4 + 3KOH \rightarrow K_3PO_4 + 3H_2O$

b. If 665.42 g of phosphoric acid (H_3PO_4) reacted, how many moles of water were produced? (2 marks)

Molar mass = 98
Moles = 6.79 moles
$6.79 \times 3 = 20.37$ moles of H_2O.

c. Consider if 8.15 mol of K_3PO_4 was produced.

i. How many moles of phosphoric acid were used up? (2 marks)

$8.15 \times 1 = 8.15$ moles

ii. How much water was also produced? (2 marks)

$8.15 \times 3 = 24.45$ moles

iii. What is the mass of KOH required to get this amount of K_3PO_4? (2 marks)

$8.15 \times 3 = 24.45$ moles of KOH, $24.45 \times (39.1 + 17) = 1371.65\ g$

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Sub-Section [2.3.3]: Identify the Limiting Reagent When Reactants' Amounts are Known

Question 41 (2 marks)

Consider the reaction:

$$Ca(OH)_2 + 2HCl \rightarrow CaCl_2 + 2H_2O$$

There are 13.00 g of $Ca(OH)_2$ and 5.00 g of HCl, determine what the limiting and excess reagents are.

0.175 moles of $Ca(OH)_2$
0.137 moles of HCl / 2 = 0.0685 moles
HCl is the limiting reagent.

Question 42 (4 marks)

9.55 g of Na_3PO_4 and 7.31 g of $CaCl_2$ are mixed and allowed to react according to this equation:

$$2Na_3PO_4 + 3CaCl_2 \rightarrow Ca_3(PO_4)_2 + 6NaCl$$

a. Which reactant is the limiting reagent? Which reactant is in excess? (2 marks)

Moles of $Na_3PO_4 = 9.55/164 = 0.0582$ moles
Moles of $CaCl_2 = 7.31 / 111.1 = 0.0658$ moles
$Na_3PO_4 = 0.0582 / 2 = 0.0291$ moles
$CaCl_2 = 0.0658/3 = 0.0219$ moles
$CaCl_2$ is the limiting reagent and Na_3PO_4 excess reagent.

b. What is the mass of $Ca_3(PO_4)_2$ that is formed? (2 marks)

$0.0658 \times 1 / 3 = 0.02193$ moles
$0.02193 \times (40.1 \times 3) + (31 + 64) \times 2 = 6.90\ g$

Question 43 (6 marks)

Consider the following reaction:

$$N_2 + 3H_2 \rightarrow 2NH_3$$

There are $14.00\ g$ of N_2 and $4.00\ g$ of H_2.

a. What are the limiting and excess reagents? (2 marks)

$14 / 28 = 0.500$ moles of N_2
$4 / 2 - 2.00$ moles of $H_2 \rightarrow 2 / 3 = 0.667$ moles of H_2 in 1:1 ratio.

b. Find the mass of NH_3 formed. (2 marks)

$0.5 \times 2 = 1.00\ mol\ NH_3$
$1 \times 17 = 17\ g$ of NH_3

c. In another experiment, if $25.5\ g$ of NH_3 was formed, how much H_2 was used initially in grams? (2 marks)

$25.5 / 17 = 1.50$ moles of NH_3
$1.50 \times 3 / 2 = 2.25$ moles of $H_2 \times 2 = 4.50\ g$ of H_2.

Question 44 (9 marks)

Consider the combustion reaction of pentane at 200°C.

a. Write the fully balanced reaction. (1 mark)

$C_5H_{12} + 8O_2 \rightarrow 5CO_2 + 6H_2O$

b. Consider an experiment where we had 44.00 g of pentane and 160.00 g of oxygen gas.

i. What are the limiting and excess reagents? (2 marks)

$44 / 72 = 0.61$ moles
$160 / 32 = 5$ moles $/ 8 = 0.625$ moles

Pentane is the limiting reagent and oxygen gas is the excess.

ii. What is the mass of gases formed? (2 marks)

$0.61 \times 5 = 3.05$ moles of $CO_2 \times 44 = 134.2\ g$
$0.61 \times 6 = 3.66$ moles of water vapour $\times 18 = 65.88\ g$
Total $= 200.08\ g$ of gas.

iii. Is this the same as the total mass of gases left over at the end of the reaction? (2 marks)

No, since there will be an amount of leftover gas at the end of the reaction from the excess reagents so it will be a bit more.

c. In another experiment, if 88.00 g of CO_2 was formed, how much O_2 was used initially in grams? (2 marks)

$88 / 44 = 2$ moles
$2 \times 8 / 5 = 3.20$ moles $\times 32 = 102.4$ g of oxygen gas.
gas.

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Sub-Section [2.3.4]: Apply Limiting Reagent to Calculate the Mass of Product(s) Formed, & the Amount of Excess Reagent Leftover

Question 45 (3 marks)

Given the following reaction:

$$CaCl_2 + NaOH \rightarrow Ca(OH)_2 + NaCl$$

a. Balance the equation. (1 mark)

$CaCl_2 + 2NaOH \rightarrow Ca(OH)_2 + 2NaCl$

b. A sample of 5.00 moles of $CaCl_2$ and 5.00 moles of NaOH reacts. What is the amount of $CaCl_2$ that would be leftover? (2 marks)

$5.00 - 2.50 = 2.50$ moles left over.

Question 46 (4 marks)

An experiment is conducted according to the following equation:

$$MnS + 2HCl \rightarrow H_2S + MnCl_2$$

If a sample contained $50.00\ g$ of MnS and $26.00\ g$ of HCl, determine the excess and limiting reagent. (2 marks

a. Which is the excess and limiting reagent? (2 marks)

$50 / 87 = 0.575$
$26 / 36.5 = 0.712 / 2 = 0.356$
HCl is limiting.

b. What is the amount leftover of the reactants? (2 marks)

Amount of MnS that reacts $= 0.712 \times \frac{1}{2} = 0.356$
$0.575 - 0.356 = 0.219$ moles of MnS left over.

Question 47 (7 marks)

Given the following reaction:

$$3Na_2CO_3(s) + 2HCl(aq) \rightarrow 6NaCl(aq) + 3CO_2(g) + H_2O(l)$$

a. Given that there was 9.40 g of sodium carbonate and 8.90 g of hydrogen chloride, find the limiting and excess reagents. (3 marks)

$9.40 / 23 + 23 + 12 + 48 = 0.0886$
$8.90 / 1 + 35.5 = 0.243$ moles of HCl
$0.0886 / 3 = 0.02867$ moles.
$0.243 / 2 = 0.122$ moles.

Therefore, the sodium carbonate is limiting, and hydrogen chloride is excess.

b. Find the mass of NaCl and CO_2 that will be produced. (2 marks)

$0.0886 \times 2 = 0.1732$ moles of NaCl $\rightarrow 0.1732 \times (23 + 35.5) = 10.13\ g$
$0.0886 \times 3 / 3 = 0.0886$ moles of carbon dioxide $\rightarrow 0.0886 \times (12 + 32) = 3.81\ g$ of CO_2

c. What is the mass of the excess reagent left over? (2 marks)

Moles reacted = $0.0886 \times 2/3 = 0.05773$ moles reacted
Left over = $0.243 - 0.05773 = 0.1853$ moles left
$0.1853 \times 36.5 = 6.76\ g$ of HCl left over.

Question 48 (9 marks)

Given the following reaction:

$$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$$

a. Given that there was $5.03\ g$ of NH_3 and $3.45\ g$ of O_2, find the limiting and excess reagents. (2 marks)

$5.03 / 17 = 0.296$ moles of NH_3
$3.45 / 32 = 0.107$ moles of O_2
$0.296 / 4 = 0.074$ moles
$0.107 / 5 = 0.0214$ moles
So, oxygen is the limiting reagent.

b. After the reaction is completed, some of the excess reagent remains.

i. Find the amount of excess reagent that is left over. (2 marks)

Moles reacted = $0.107 \times 4 / 5 = 0.0856$ moles reacted.
Left over = $0.296 - 0.0856 = 0.210$ moles left.

ii. Find the mass of the excess reagent that is left over. (1 mark)

$0.210 \times 17 = 3.58\ g$ left over.

iii. Find the mass of gases produced. (2 marks)

$0.107 \times 4 / 5 = 0.0856$ moles
$0.0856 \times 30 = 2.568\ g$ of NO
$0.107 \times 6 / 5 = 0.1284$ moles $\times\ 18 = 2.311\ g$ of H_2O

c. What is the amount, in grams, of the current limiting reagent we need to add to turn the reaction into one where the reactants fully react? (2 marks)

We need there to be no left over, so the amount needs to be 0.210 moles of O_2 added. As such $0.210 \times 32 = 6.72\ g$ of oxygen gas needed.

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Section D: [2.1-2.3] Overall (VCAA Qs) (60 Marks)

Question 49 (3 marks)

Find the number of particles in the following:

a. In 2 moles of O_2, find the number of oxygen atoms. (1 mark)

$2 \times 2 = 4$ moles of $O \rightarrow 4 \times 6.02 \times 10^{23} = 2.408 \times 10^{24}$ oxygen atoms.

b. In 4 moles of $CaCl_2$, find the number of chloride ions. (1 mark)

$4 \times 2 = 8$ moles of $Cl \rightarrow 8 \times 6.02 \times 10^{23} = 4.816 \times 10^{24}$

c. If there are 9.03×10^{24} particles of fluorine atoms in a sample of F_2 gas, find the number of moles of F_2. (1 mark)

$9.03 \times 10^{24} / 2 = 4.515 \times 10^{24}$ of F_2 / $6.02 \times 10^{23} = 7.5$ moles

Question 50 (5 marks)

For the following samples, calculate the amount required.

a. Given that there is 5.0 g of CO_2, calculate the moles present. (1 mark)

$5 / (12 + 32) = 0.1136\ mol$

b. Given that there is 14.6 g of NH_3, calculate the moles of ammonia. (1 mark)

$14.6 / 17 = 0.8588\ mol$

c. Given that there are 1.50 moles of $CaCl_2$, calculate the mass present. (1 mark)

$1.5 \times (40.1 + 35.5 + 35.5) = 166.65\ g$

d. Given that there are 3.00 moles of K_2SO_4, calculate the mass present. (1 mark)

$3 \times (39.1 + 39.1 + 32.1 + 64) = 522.9\ g$

e. Given that there is $4.56 \times 10^{-3}\ mol$ Na_2CO_3, calculate the mass present. (1 mark)

$4.56 \times 10^{-3} \times (23 + 23 + 12 + 48) = 0.483\ g$

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Question 51 (2 marks)

Neon has three naturally occurring isotopes: Ne-20, Ne-21, Ne-22. Their relative abundances are 90.48%, 0.27%, and 9.25% respectively. Calculate the relative atomic mass of neon.

$0.9048 \times 20 + (0.0027 \times 21) + (0.0925 \times 22) = 20.19\ g\ mol^{-1}$

Question 52 (2 marks)

The relative atomic mass of an element Y is 10.81. It has two isotopes: Y-10 and Y-11. Determine the percentage abundance of each isotope.

$10.81 = 10x + (1 - x)11$

$X = 0.19 \rightarrow$ Y-10: : 19% and Y-11: 81%

Question 53 (4 marks)

For the following, find the percentage composition of all the elements in the compound.

a. $Mg_3(PO_4)_2$. (2 marks)

Molar mass $= (24.3 \times 3) + (2 \times 31) + (8 \times 16) = 262.9$

$Mg = 24.3 \times 3 / 262.9 = 27.73\%$

$P = (31 \times 2) / 262.9 = 23.58\%$

$O = (8 \times 16) / 262.9 = 48.69\%$

b. $Ca(NO_3)_2$. (2 marks)

Molar mass $= 40.1 + 14 \times 2 + 16 \times 6 = 164.1$
Ca $= 40.1 / 164.1 = 24.44\%$
N $= 28 / 164.1 = 17.06\%$
O $= 58.50\%$

Question 54 (4 marks)

The following reaction occurred in an experiment:

$$FeCl_3 + 3NaOH \rightarrow Fe(OH)_3 + 3NaCl$$

There are 1.80 $grams$ of $FeCl_3$ and 4.20 grams of NaOH.

a. What are the limiting and excess reagents? (2 marks)

$$n(FeCl_3) = \frac{1.80}{55.8 + 35.5 \times 3} = 0.01109\ mol$$
$$n_{eff}(Fecl_3) = \frac{0.01109}{1}$$
$$= 0.01109$$
$$n(NaOH) = \frac{4.20\ g}{(23.0 + 17.0)\ g/mol} = 0.105\ mol$$
$$n_{eff}(NaOH) = \frac{0.105\ mol}{3} = 0.035$$

$FeCl_3$ is the limiting reagent.

b. Find the mass of NaCl and $Fe(OH)_3$ formed. (2 marks)

$0.01109 \times 3 = 0.03327\ mol$ of NaCl $\times\ 23 + 35.5 = 1.95\ g$ of NaCl formed
$0.01109 \times 55.8 + 17 \times 3 = 1.18\ g$ of $Fe(OH)_3$ formed.

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Question 55 (5 marks)

Consider the compound, ammonium sulphate, $(NH_4)_2SO_4$.

a. What is its molar mass? (1 mark)

$14 \times 2 + 8 + 32.1 + 64 = 132.1\ g\ mol^{-1}$ of ammonium sulphate.

b. Given that a sample contains $4.28 \times 10^{-3}\ kg$, what is the number of moles present in ammonium sulphate? (2 marks)

$4.28 \times 10^{-3}\ kg = 4.28\ g\ /\ 132.1 = 0.03239\ mol$

c. Now, based on your answer, find the mass of nitrogen in the sample, expressed in micrograms. (2 marks)

$0.03239 \times 2 = 0.06479\ mol$ of nitrogen $\times\ 14 = 0.907\ g \times 10^6 = 9.07 \times 10^5$ micrograms

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Question 56 (5 marks)

Consider the compound of $Ca(NO_3)_3$.

a. What is the molar mass? (1 mark)

$40.1 + 14 \times 3 + 9 \times 16 = 226.1\ g\ mol^{-1}$

b. Given that a sample contains $6.240 \times 10^{-4}\ kg$, what is the number of moles present in the compound? (2 marks)

$0.624\ g\ /\ 226.1 = 0.002759\ mol$

c. Based on your answer, find the atoms of oxygen in the sample. (2 marks)

$0.002759 \times 9 \times 6.02 \times 10^{23} = 1.50 \times 10^{22}$ atoms of oxygen.

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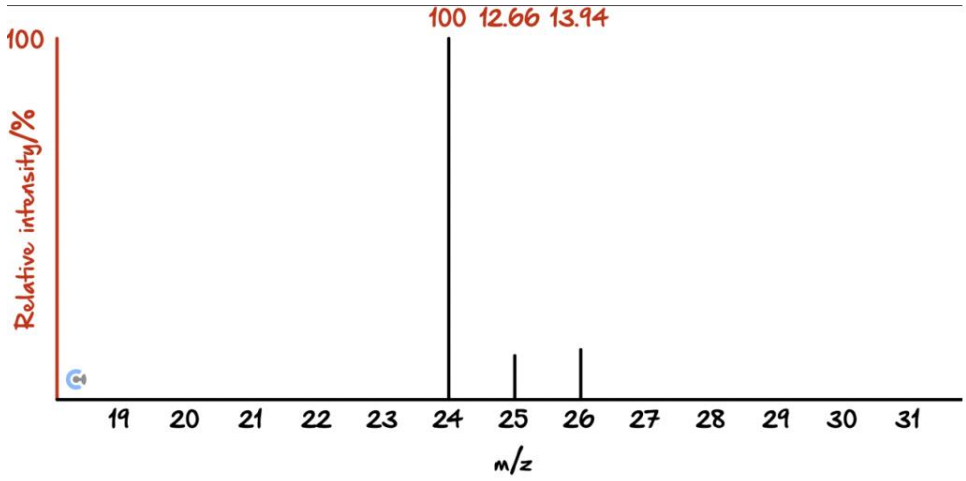
Question 57 (3 marks)

Find the relative atomic mass given the following mass spectrum and identify the compound.



$24.3\ g\ mol^{-1}$ → Magnesium

Question 58 (7 marks)

Consider the reaction:

$$Ca(OH)_2\ (aq)\ +\ 2HCl\ (aq) \rightarrow\ CaCl_2\ (aq)\ +\ 2H_2O\ (l)$$

a. If there are $2.78\ g$ of $Ca(OH)_2$ and $3.65\ g$ of HCl, find the limiting reagent. (3 marks)

$2.78\ /\ (40.1\ +\ 17\ +\ 17)\ =\ 0.0375\ mol\ Ca(OH)_2$
$3.65\ /\ 36.5\ =\ 0.10\ mol\ HCl \rightarrow\ 0.05\ mol\ HCl\ \rightarrow\ Ca(OH)_2$ the limiting reagent.

b. What mass of the excess reagent will be left over? (2 marks)

Amount of HCl reacting $= 0.0375 \times 2 = 0.075$
Leftover $= 0.10 - 0.075 = 0.025\ mol$ of HCl leftover $\times 36.5 = 0.9125\ g$ HCl left.

c. If 9.88 g of $CaCl_2$ was produced, what is the mass of $Ca(OH)_2$ required to produce this, assuming the reaction is 100% efficient? (2 marks)

$9.88 / (40.1 + 35.5 \times 2) = 0.0889\ mol = n(Ca(OH)_2)$
$0.0889 \times 40.1 + 17 + 17 = 6.59\ g$

Question 59 (10 marks)

Consider an experiment where the aim is to experimentally determine Avogadro's number using a sample of aluminium sulphate, $Al_2(SO_4)_3$.

a. What is the molar mass of aluminium sulphate? (1 mark)

$27 + 27 + 32.1 \times 3 + 12 \times 16 = 342.3\ g\ mol^{-1}$

b. Calculate the number of moles of aluminium sulphate in a 52 mg sample. (2 marks)

$52 \times 10^{-3}\ g / 342.3 = 1.52 \times 10^{-4}\ mol$

c. Given that the sample we know has 2.508×10^{20} atoms of sulphur, calculate the experimental value of Avogadro's number. (3 marks)

$2.508 \times 10^{20} / 3 = 8.36 \times 10^{19}$ atoms of the aluminium sulphate
$N_a = N / n = 8.36 \times 10^{19} / 1.52 \times 10^{-4} = 5.50 \times 10^{23}\ mol^{-1}$

d. Explain whether this experimental value is accurate. (2 marks)

As the true value of Avogadro's number is 6.02×10^{23}, this is about 91% of that value, which means it is fairly close but not quite accurate to the true value.

e. Briefly explain why Avogadro's number has the units it does. (2 marks)

As Avogadro's number states the number of molecules per mol of any compound, we can express as a counting unit as (molecules per mol) but since molecules are just "objects" we don't give them a unit, hence mol^{-1} (per mol).

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Question 60 (10 marks)

Given the following reaction:

$$Al(s) + Cl_2(g) \rightarrow AlCl_3(s)$$

a. Balance the reaction. (1 mark)

$2Al\,(s) + 3Cl_2 \rightarrow 2AlCl_3$

b. If 5.40 g of aluminium is reacted, how much aluminium chloride would be produced? (2 marks)

$5.40 / 27 = 0.2\,mol = n(AlCl_3)$
$0.2 \times 27 + 35.5 \times 3 = 26.7\,g$ produced.

c. If there is 5.40 g of Al and 9.48 g of Cl_2, which is the limiting and excess reagent? (3 marks)

$5.40 / 27 = 0.20$ moles $/ 2 = 0.10$
$9.48 / 35.5 = 0.1335$ moles of $Cl_2 / 3 = 0.0445 \rightarrow$ Chlorine is the limiting reagent.

d. Find the mass of $AlCl_3$ produced. (2 marks)

$0.1335 \times 2/3 = 0.089$ moles of $AlCl_3 \times (27 + 35.5 \times 3) = 11.88\,g$

e. How much of the excess reagent, in kg, is left at the end of the reaction? (2 marks)

$0.1335 \times 2 / 3 = 0.089$ moles Al reacted
Leftover $= 0.20 - 0.089 = 0.111$ moles of Al left
$0.111 \times 27 \times 10^{-3} = 3.0 \times 10^{-3}\ kg$

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