1 Ammonia, NH_3, and hydrazine, N_2H_4, are both bases.

(a) Ammonium sulfate, $(NH_4)_2SO_4$, can be prepared by reacting ammonia with sulfuric acid, H_2SO_4.

(i) Why can ammonium sulfate be described as a salt?

.....

..... **[1]**

(ii) A student was given 400 cm^3 of aqueous ammonia solution, $NH_3(aq)$. The student was asked to determine how many moles of NH_3 had been dissolved to prepare the solution.

The student titrated 25.0 cm^3 of $NH_3(aq)$ and found that it reacted exactly with 32.5 cm^3 of 0.100 mol dm^{-3} sulfuric acid.

The equation for this reaction is shown below.

$$2NH_3(aq) + H_2SO_4(aq) \rightarrow (NH_4)_2SO_4(aq)$$

Calculate the amount, in moles, of NH_3 in the original 400 cm^3 solution.

answer = ... mol **[3]**

(b) The hydrazine molecule, $H_2N–NH_2$, is covalent.

Predict the H–N–H bond angle in a hydrazine molecule.

Explain your answer.

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..... **[4]**

(c) Like ammonia, hydrazine is a base that reacts with water to form negative and positive ions.

(i) Write the formula of the negative ion that is formed when hydrazine reacts with water.

..... **[1]**

(ii) Suggest the formula of a positive ion which might form when hydrazine reacts with water.

..... **[1]**

(d) Hydrazine, N_2H_4, has found a use as rocket fuel.

The overall equation for the production of hydrazine is shown below.

$$2NH_3 + NaCl O \rightarrow N_2H_4 + NaCl + H_2O$$

(i) Using oxidation numbers, explain why the above equation represents a redox reaction.

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..... **[3]**

(ii) What is the name for NaClO?

..... **[1]**

(iii) The overall reaction takes place in two stages.

- In the first stage NH_2Cl is produced.
- In the second stage N_2H_4 is produced.

Some of the hydrazine reacts with NH_2Cl to form ammonium chloride and a colourless gas with a relative molecular mass of 28.0.

Construct the equation for this reaction.

..... **[2]**

[Total: 16]

2 Sir Humphrey Davy, the inventor of the miners' safety lamp, was the first person to isolate the element strontium. Robert Bunsen, the inventor of the Bunsen burner, was partly responsible for the discovery of the element rubidium. Rubidium and strontium occur next to each other in the Periodic Table.

A sample of rubidium was analysed and found to consist of two isotopes, rubidium-85 and rubidium-87. Information about these isotopes is given in the table.

isotope	relative isotopic mass	abundance (%)
rubidium-85	85.00	72.15
rubidium-87	87.00	27.85

(a) In terms of sub-atomic particles, what is the difference between these isotopes of rubidium?

.....

..... **[1]**

(b) Define the term *relative atomic mass*.

.....

.....

.....

..... **[3]**

(c) Calculate the relative atomic mass of the sample of rubidium.

Give your answer to **two** decimal places.

answer = ... **[2]**

(d) Both rubidium, a Group 1 element, and strontium, a Group 2 element, have their outermost electrons in the 5s orbital.

What 3-D shape is the 5s orbital?

..... **[1]**

(e) Ionisation energies allow chemists to determine electron structures. The first two ionisation energies of rubidium and strontium are shown in the table.

element	first ionisation energy / kJ mol^{-1}	second ionisation energy / kJ mol^{-1}
rubidium	403	2632
strontium	550	1064

(i) Write an equation to represent the **second** ionisation energy of strontium.

Include state symbols.

..... **[1]**

(ii) Why is the **first** ionisation energy of strontium larger than the **first** ionisation energy of rubidium?

In your answer you should use appropriate technical terms spelled correctly.

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..... **[3]**

(iii) Why is the **second** ionisation energy of rubidium larger than the **second** ionisation energy of strontium?

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..... **[2]**

[Total: 13]

3 Sodium tartrate and copper(II) nitrate are both salts.

(a) Sodium tartrate is a salt of tartaric acid. The formula of tartaric acid can be represented as H_xA. In this formula, x is the number of H^+ ions that can be replaced by metal ions to form salts.

A student carries out a titration to find the value of x in the formula of tartaric acid, H_xA.
In the titration, 25.00 cm^3 of 0.0500 mol dm^{-3} tartaric acid, H_xA, exactly reacts with 12.50 cm^3 of 0.200 mol dm^{-3} sodium hydroxide, NaOH. A solution of sodium tartrate is produced.

(i) Calculate the amount, in mol, of H_xA used.

amount = ... mol **[1]**

(ii) Calculate the amount, in mol, of NaOH used.

amount = ... mol **[1]**

(iii) Deduce the value for x in the formula of tartaric acid, H_xA.

x = ... **[1]**

(b) Copper(II) nitrate is a salt of nitric acid.

(i) A student prepares a solution of copper(II) nitrate, $Cu(NO_3)_2$, by adding, with stirring, an excess of copper(II) oxide to some hot dilute nitric acid.

Construct the equation for this reaction.

..... **[2]**

(ii) Copper(II) nitrate has ionic bonding.

What is meant by the term *ionic bonding*?

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..... **[1]**

(iii) Explain why a solution of copper(II) nitrate conducts electricity.

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..... **[1]**

(iv) What is the oxidation number of nitrogen in $Cu(NO_3)_2$?

..... **[1]**

(c) Hydrated crystals of copper(II) nitrate can be prepared by allowing water to evaporate from a solution of copper(II) nitrate.

Hydrated copper(II) nitrate has the empirical formula $CuN_2O_{12}H_{12}$.

Write the formula of hydrated copper(II) nitrate to show its water of crystallisation.

..... **[1]**

[Total: 9]

4 Calcium hydroxide is used in agriculture but the amounts used must be carefully controlled.

(a) State **one** use of calcium hydroxide in agriculture **and** suggest why the amount of calcium hydroxide used should not be excessive.

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..... **[2]**

(b) A student knew that calcium hydroxide could be made by adding calcium to water.

The student added 0.00131 mol of calcium to a beaker containing about 100 cm^3 of water.
A reaction took place as shown by the equation below.
All the calcium hydroxide formed was soluble.

$$Ca(s) + 2H_2O(l) \rightarrow Ca(OH)_2(aq) + H_2(g)$$

(i) Calculate the mass of calcium that the student added.

mass of calcium = ... g **[1]**

(ii) Calculate the volume of hydrogen gas, in dm^3, produced in this reaction at room temperature and pressure, RTP.

volume of hydrogen gas = ... dm^3 **[1]**

(iii) The student transferred the contents of the beaker to a 250 cm^3 volumetric flask and water was added to make the solution up to 250 cm^3.

Calculate the concentration, in mol dm^{-3}, of **hydroxide ions** in the 250 cm^3 solution.

concentration = ... mol dm^{-3} **[2]**

(c) The student repeated the experiment using the same mass of pure barium.

The student found that a smaller volume of hydrogen gas was produced, measured at RTP.

(i) Explain why.

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..... **[1]**

(ii) Suggest **one** other difference the student would observe between the reactions of water with calcium and of water with barium.

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..... **[1]**

[Total: 8]

5 Europium, atomic number 63, is used in some television screens to highlight colours. A chemist analysed a sample of europium using mass spectrometry. The results are shown in **Table 1.1** below.

isotope	relative isotopic mass	abundance (%)
^{151}Eu	151.0	47.77
^{153}Eu	153.0	52.23

Table 1.1

(a) Define the term *relative isotopic mass*.

.....

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..... **[2]**

(b) Using **Table 1.1**, calculate the relative atomic mass of the europium sample.
Give your answer to **two** decimal places.

answer = …… **[2]**

(c) Isotopes of europium have differences and similarities.

(i) In terms of protons, neutrons and electrons, how is an atom of ^{151}Eu **different** from an atom of ^{153}Eu?

.....

..... **[1]**

(ii) In terms of protons, neutrons and electrons, how is an atom of ^{151}Eu **similar** to an atom of ^{153}Eu?

.....

..... **[1]**

(d) Modern plasma television screens emit light when mixtures of noble gases, such as neon and xenon, are ionised.

The first ionisation energies of neon and xenon are shown in the table below.

element	**1st ionisation energy / kJ mol^{-1}**
neon	+2081
xenon	+1170

Explain why xenon has a lower first ionisation energy than neon.

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..... **[3]**

[Total: 9]

6 A student carries out experiments using acids, bases and salts.

(a) Calcium nitrate, $Ca(NO_3)_2$, is an example of a salt.

The student prepares a solution of calcium nitrate by reacting dilute nitric acid, HNO_3, with the base calcium hydroxide, $Ca(OH)_2$.

(i) Why is calcium nitrate an example of a salt?

.....

..... **[1]**

(ii) Write the equation for the reaction between dilute nitric acid and calcium hydroxide. Include state symbols.

..... **[2]**

(iii) Explain how the hydroxide ion in aqueous calcium hydroxide acts as a base when it neutralises dilute nitric acid.

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..... **[1]**

(b) A student carries out a titration to find the concentration of some sulfuric acid.

The student finds that 25.00 cm^3 of 0.0880 $mol\,dm^{-3}$ aqueous sodium hydroxide, NaOH, is neutralised by 17.60 cm^3 of dilute sulfuric acid, H_2SO_4.

$$H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$$

(i) Calculate the amount, in moles, of NaOH used.

answer = …… mol **[1]**

(ii) Determine the amount, in moles, of H_2SO_4 used.

answer = …… mol **[1]**

(iii) Calculate the concentration, in $mol\,dm^{-3}$, of the sulfuric acid.

answer = …… $mol\,dm^{-3}$ **[1]**

(c) After carrying out the titration in **(b)**, the student left the resulting solution to crystallise. White crystals were formed, with a formula of $Na_2SO_4 \bullet \boldsymbol{x} H_2O$ and a molar mass of 322.1 $g\,mol^{-1}$.

(i) What term is given to the '$\bullet \boldsymbol{x} H_2O$' part of the formula?

..... **[1]**

(ii) Using the molar mass of the crystals, calculate the value of $\boldsymbol{x}$.

answer = …… **[2]**

[Total: 10]