1 This question is about the element chlorine and its compounds.

(a) When chlorine is bubbled through water, a solution of chlorine water forms. What is the colour of chlorine water?

(1)

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(b) Chlorine water is added to potassium iodide solution.

(i) State the colour of the solution produced.

(1)

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(ii) Write the **ionic** equation for the reaction, including state symbols.

(2)

(c) The concentration of chlorine water was found by taking 10.0 cm^3 of solution, adding an excess of potassium iodide solution, and titrating with 0.0100 mol dm^{-3} of sodium thiosulfate solution. The experiment was repeated.

The following results were obtained.

Titration number	1	2
Final burette reading / cm^3	38.60	47.60
Initial burette reading / cm^3	29.50	38.60
Volume added / cm^3	9.10	9.00

(i) Name a suitable indicator for the titration. State the colour change you would expect to see at the end point.

(2)

Indicator .....

Colour change from ..... to .....

(ii) Calculate the mean titre and use this value to calculate the number of moles of sodium thiosulfate used in the titration.

(1)

Mean titre ..... cm^3

Moles of sodium thiosulfate

(iii) Complete the ionic equation for the reaction between iodine and thiosulfate ions.

(2)

$I_2(aq) + 2S_2O_3^{2}\ (aq) \rightarrow$

(iv) Calculate the number of moles of iodine which reacted with the sodium thiosulfate solution.

(1)

(v) Hence state the number of moles of chlorine present in 10.0 cm^3 of the chlorine water.

(1)

(vi) Calculate the concentration of the chlorine water, in mol dm^{3}.

(1)

(d) Potassium burns in chlorine to form potassium chloride.

(i) Give the colour of the flame when potassium burns in chlorine.

(1)

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(ii) Write the equation for the reaction between potassium and chlorine. State symbols are **not** required.

(1)

(e) Concentrated sulfuric acid is added to potassium chloride in a test tube. Steamy fumes are given off which react with ammonia to give dense white smoke.

(i) Name the gas given off in this reaction.

(1)

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(ii) Steamy fumes are observed at the mouth of the test tube. Explain how these fumes are formed.

(1)

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(iii) The steamy fumes react with ammonia to give a dense white smoke. Identify the white smoke by name or formula.

(1)

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(f) 2-chlorobutane can be made from butan-2-ol.

(i) Name the chemical you would add to butan-2-ol in the laboratory to make 2-chlorobutane.

(1)

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(ii) 2-chlorobutane reacts with alcoholic potassium hydroxide at a high temperature to form a mixture of gaseous alkenes.

Draw a fully labelled diagram of the apparatus you would use to prepare and collect this mixture.

(3)

(Total for Question 21 marks)

2 A student carried out an experiment to determine the concentration of ethanoic acid in a solution of vinegar.

- The student used a measuring cylinder to measure out 25.0 cm^3 of the vinegar solution.
- This solution was then transferred to a 250 cm^3 volumetric flask and the liquid level was carefully made up to the mark with distilled water.
- A pipette was used to transfer 25.0 cm^3 portions of the acidic solution to conical flasks.
- The solution was then titrated with sodium hydroxide solution, concentration 0.100 mol dm^{-3}, using phenolphthalein as the indicator.

$$CH_3COOH(aq) + NaOH(aq) \rightarrow CH_3COONa(aq) + H_2O(l)$$

Results

Titration number	1	2	3	4
Burette reading (final) / cm^3	28.55	28.00	40.35	28.05
Burette reading (initial) / cm^3	0.00	0.05	12.30	0.05
Volume of NaOH used / cm^3	28.55	27.95	28.05	28.00

(a) In this titration, what is the colour change of the phenolphthalein indicator?

(2)

From **to**

(b) Explain why the mean titre should be based only on titrations 2, 3 and 4.

(1)

(c) Calculate the mean titre in cm^3.

(1)

(d) (i) Using your answer to (c), calculate the number of moles of sodium hydroxide in the mean titre.

(1)

(ii) Hence state the number of moles of ethanoic acid, CH_3COOH, in 25.0 cm^3 of the **diluted** solution used in the titration.

(1)

(iii) Calculate the concentration of the **diluted** acid solution in mol dm^{-3}.

(1)

(iv) Hence calculate the concentration of the ethanoic acid in the **original** vinegar solution in mol dm^{-3}.

(1)

(v) Use your answer from (d)(iv) to state the concentration of the ethanoic acid in the **original** vinegar solution in units of g dm^{-3}.

[The molar mass of the ethanoic acid is 60 g mol^{-1}.]

(1)

(e) Suggest, with a reason, how the student's method of preparing the diluted solution could be improved.

(2)

Improvement

Reason

(f) The burette used in the titration had an uncertainty for each reading of ± 0.05 cm^3.

(i) Identify, by letter, which ONE of the following should be regarded as the true value of the titre in titration number **2**?

X Between 27.90 and 28.00 cm^3

Y Between 27.925 and 27.975 cm^3

Z Between 27.85 and 28.05 cm^3

(1)

(ii) Suggest ONE reason why a student may obtain volumes outside the uncertainty of the burette when performing a titration.

(1)

(Total for Question = 13 marks)

3 This question is about the preparation of the alum, potassium aluminium sulfate, $KAl(SO_4)_2 \cdot 12H_2O$. It is a double salt consisting of potassium ions, aluminium ions and sulfate ions, and water of crystallization.

(a) The first step of the preparation involves adding an excess of aluminium foil to 10 cm^3 of 2 mol dm^{-3} potassium hydroxide to form potassium aluminate.

The equation for this reaction is

$$2Al(s) + 2KOH(aq) + 2H_2O(l) \rightarrow 2KAlO_2(aq) + 3H_2(g)$$

(i) Write a balanced **ionic** equation for this reaction.

(1)

(ii) Calculate the number of moles of potassium hydroxide used.

(1)

(iii) Hence state the number of moles of aluminium that react with the potassium hydroxide.

(1)

(iv) Use your answer to (iii) to calculate the mass of aluminium that reacts with the potassium hydroxide. Use the Periodic Table as a source of data.

(1)

(v) Calculate the total mass of aluminium added to the potassium hydroxide if a 10% excess of aluminium is required.

(1)

(vi) Identify **two** hazards in this first step of the preparation.

(2)

Hazard 1 .....

.....

Hazard 2 .....

.....

(b) The second step of the reaction is the addition of a slight excess of 1 mol dm^{-3} sulfuric acid.

(i) Balance the following equation for the reaction

(1)

$$KAlO_2(aq) + H_2SO_4(aq) \rightarrow KAl(SO_4)_2(aq) + H_2O(l)$$

(ii) Calculate the volume of the 1 mol dm^{-3} sulfuric acid that reacts with the potassium aluminate.

(1)

(iii) State how you would show that the acid had been added in excess.

(2)

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*(iv) State and explain the steps necessary to obtain pure, dry crystals from the mixture.

(4)

(v) Suggest the colour of the crystals.

(1)

(vi) Suggest the formula of another metal ion which could form an alum, in combination with potassium and sulfate ions.

(1)

(Total for Question = 17 marks)

4 Hydrogen has three isotopes, ^{1}H, known as protium, ^{2}H, deuterium, and ^{3}H, tritium.

(a) In terms of sub-atomic particles, give the similarities and differences between atoms of these three isotopes of hydrogen.

(3)

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(b) When a nitrogen atom collides with a high energy neutron, one atom of tritium and one atom of another element are formed. Complete the equation below.

(1)

$$^{14}_{7}N + {}^{1}_{0}n \rightarrow {}^{3}_{1}H + \text{.....}$$

(c) Tritium-deuterium gas, consisting of molecules each containing one deuterium atom and one tritium atom, is used in some nuclear warheads. Typically, each warhead has about 4.0 g of the gas added.

(i) Calculate the number of moles of tritium-deuterium in 4.0 g.

(2)

(ii) Calculate the volume, in cm^3, of 4.0 g of tritium-deuterium gas.

[Molar volume of a gas under these conditions = 24 000 $cm^3\ mol^{-1}$]

(1)

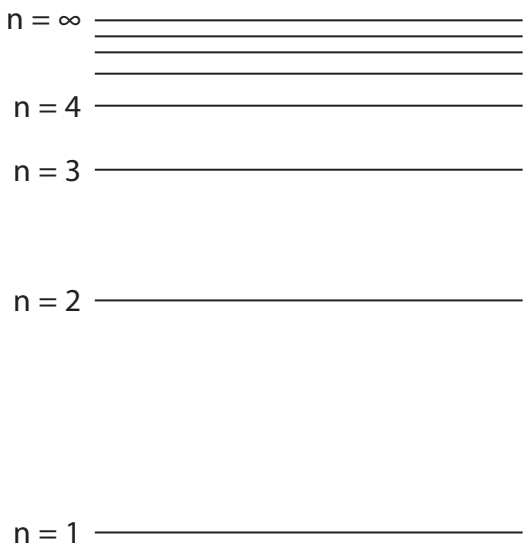
(d) Tritium is not usually included in calculations of the relative atomic mass of hydrogen, because it is radioactive and has a relatively short half-life.

Calculate the relative atomic mass of hydrogen with the following isotopic composition. Give your answer to four decimal places.

(2)

Isotope	Mass number	Relative abundance
^{1}H	1.0078	99.9850
^{2}H	2.0141	0.0150

(e) The electronic energy levels in hydrogen are shown below.



(i) Mark on the energy level diagram, with an arrow, the transition that represents the ionization energy of hydrogen.

(1)

(ii) In some versions of the Periodic Table, hydrogen is placed in the same group as sodium. Give the electronic configurations for both a hydrogen atom and a sodium atom, using the *s* and *p* notation.

Use these electronic configurations to suggest why this is a reasonable grouping.

(2)

H .....

Na .....

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*(f) Which element in the Periodic Table has the highest first ionization energy? Justify your answer.

(3)

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(Total for Question = 15 marks)