TUTOR ZONE

Percentage	
Grade	

A Level Chemistry

Mole Calculations

Duration: 1 hour 15 min

Total Marks: 69

Information for Candidates:

- Use black or blue ink. HB pencil may be used for graphs and diagrams only.
- Answer **all** the questions.
- Read each question carefully. Make sure you know what you have to do before starting your answer.
- Write your answer to each question in the space provided. If additional paper is used, the question number(s) must be clearly shown
- The number of marks is given in brackets **[ ]** at the end of each question or part question.
- You may use an electronic calculator.
- You are advised to show all the steps in any calculations.

Do not write in this table	
Question	Mark
TOTAL	

2 Ammonium sulfate reacts with sodium hydroxide to form ammonia, sodium sulfate and water as shown in the equation below.

$$(NH_4)_2SO_4(s) + 2NaOH(aq) \longrightarrow 2NH_3(g) + Na_2SO_4(aq) + 2H_2O(l)$$

2 (a) A 3.14 g sample of ammonium sulfate reacted completely with 39.30 cm^3 of a sodium hydroxide solution.

2 (a) (i) Calculate the amount, in moles, of $(NH_4)_2SO_4$ in 3.14 g of ammonium sulfate.

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(2 marks)

2 (a) (ii) Hence calculate the amount, in moles, of sodium hydroxide which reacted.

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(1 mark)

2 (a) (iii) Calculate the concentration, in mol dm^{-3}, of the sodium hydroxide solution used.

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(1 mark)

2 (b) Calculate the percentage atom economy for the production of ammonia in the reaction between ammonium sulfate and sodium hydroxide.

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(2 marks)

2 (c) Ammonia is manufactured by the Haber Process.

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

Calculate the percentage atom economy for the production of ammonia in this process.

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(1 mark)

2 (d) A sample of ammonia gas occupied a volume of 1.53×10^{-2} m^3 at 37 °C and a pressure of 100 kPa.
(The gas constant $R = 8.31\,J\,K^{-1}\,mol^{-1}$)

Calculate the amount, in moles, of ammonia in this sample.

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(3 marks)

(Extra space) .....

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2 (e) Glauber's salt is a form of hydrated sodium sulfate that contains 44.1% by mass of sodium sulfate. Hydrated sodium sulfate can be represented by the formula $Na_2SO_4.xH_2O$ where x is an integer. Calculate the value of x.

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(3 marks)

(Extra space) .....

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13

2 Norgessaltpeter was the first nitrogen fertiliser to be manufactured in Norway. It has the formula $Ca(NO_3)_2$

2 (a) Norgessaltpeter can be made by the reaction of calcium carbonate with dilute nitric acid as shown by the following equation.

$$CaCO_3(s) + 2HNO_3(aq) \longrightarrow Ca(NO_3)_2(aq) + CO_2(g) + H_2O(l)$$

In an experiment, an excess of powdered calcium carbonate was added to 36.2 cm^3 of 0.586 mol dm^{-3} nitric acid.

2 (a) (i) Calculate the amount, in moles, of HNO_3 in 36.2 cm^3 of 0.586 mol dm^{-3} nitric acid. Give your answer to 3 significant figures.

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(1 mark)

2 (a) (ii) Calculate the amount, in moles, of $CaCO_3$ that reacted with the nitric acid. Give your answer to 3 significant figures.

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(1 mark)

2 (a) (iii) Calculate the minimum mass of powdered $CaCO_3$ that should be added to react with all of the nitric acid. Give your answer to 3 significant figures.

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(2 marks)

2 (a) (iv) State the type of reaction that occurs when calcium carbonate reacts with nitric acid.

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(1 mark)

2 (b) Norgessaltpeter decomposes on heating as shown by the following equation.

$$2Ca(NO_3)_2(s) \longrightarrow 2CaO(s) + 4NO_2(g) + O_2(g)$$

A sample of Norgessaltpeter was decomposed completely.

The gases produced occupied a volume of $3.50 \times 10^{-3}\,m^3$ at a pressure of 100 kPa and a temperature of 31 °C.
(The gas constant $R = 8.31\,J\,K^{-1}\,mol^{-1}$)

2 (b) (i) Calculate the total amount, in moles, of gases produced.

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(3 marks)

2 (b) (ii) Hence calculate the amount, in moles, of oxygen produced.

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(1 mark)

2 (c) Hydrated calcium nitrate can be represented by the formula $Ca(NO_3)_2.xH_2O$ where x is an integer.

A 6.04 g sample of $Ca(NO_3)_2.xH_2O$ contains 1.84 g of water of crystallisation.

Use this information to calculate a value for x.
Show your working.

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(3 marks)

12

Turn over ▶

Section B

Answer **all** questions in the spaces provided.

6 The metal lead reacts with warm dilute nitric acid to produce lead(II) nitrate, nitrogen monoxide and water according to the following equation.

$$3Pb(s) + 8HNO_3(aq) \longrightarrow 3Pb(NO_3)_2(aq) + 2NO(g) + 4H_2O(l)$$

6 (a) In an experiment, an 8.14 g sample of lead reacted completely with a 2.00 mol dm^{-3} solution of nitric acid.

Calculate the volume, in dm^3, of nitric acid required for complete reaction.
Give your answer to 3 significant figures.

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(3 marks)

(Extra space) .....

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6 (b) In a second experiment, the nitrogen monoxide gas produced in the reaction occupied 638 cm^3 at 101 kPa and 298 K.
Calculate the amount, in moles, of NO gas produced.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

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(3 marks)

(Extra space) .....

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6 (c) When lead(II) nitrate is heated it decomposes to form lead(II) oxide, nitrogen dioxide and oxygen.

6 (c) (i) Balance the following equation that shows this thermal decomposition.

.....$Pb(NO_3)_2(s)$ ⟶ ..... $PbO(s)$ + ...$NO_2(g)$ + ...$O_2(g)$

(1 mark)

6 (c) (ii) Suggest **one** reason why the yield of nitrogen dioxide formed during this reaction is often less than expected.

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(1 mark)

6 (c) (iii) Suggest **one** reason why it is difficult to obtain a pure sample of nitrogen dioxide from this reaction.

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(1 mark)

9

Section B

Answer **all** questions in the spaces provided.

5 Ammonia is used to make nitric acid (HNO_3) by the Ostwald Process.
Three reactions occur in this process.

Reaction **1** $4NH_3(g) + 5O_2(g) \longrightarrow 4NO(g) + 6H_2O(g)$

Reaction **2** $2NO(g) + O_2(g) \longrightarrow 2NO_2(g)$

Reaction **3** $3NO_2(g) + H_2O(l) \longrightarrow 2HNO_3(aq) + NO(g)$

5 (a) In one production run, the gases formed in Reaction **1** occupied a total volume of 4.31 m^3 at 25 °C and 100 kPa.

Calculate the amount, in moles, of NO produced.
Give your answer to 3 significant figures.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

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(4 marks)

(Extra space) .....

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5 (b) In another production run, 3.00 kg of ammonia gas were used in Reaction **1** and all of the NO gas produced was used to make NO_2 gas in Reaction **2**.

5 (b) (i) Calculate the amount, in moles, of ammonia in 3.00 kg.

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(2 marks)

5 (b) (ii) Calculate the mass of NO_2 formed from 3.00 kg of ammonia in Reaction **2** assuming an 80.0% yield.
Give your answer in kilograms.
(If you have been unable to calculate an answer for part **(b) (i)**, you may assume a value of 163 mol. This is **not** the correct answer.)

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(3 marks)

(Extra space) .....

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Question 5 continues on the next page

5 (c) Consider Reaction **3** in this process.

$$3NO_2(g) + H_2O(l) \longrightarrow 2HNO_3(aq) + NO(g)$$

Calculate the concentration of nitric acid produced when 0.543 mol of NO_2 is reacted with water and the solution is made up to 250 cm^3.

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(2 marks)

(Extra space) .....

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5 (d) Suggest why a leak of NO_2 gas from the Ostwald Process will cause atmospheric pollution.

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(1 mark)

5 (e) Give **one** reason why excess air is used in the Ostwald Process.

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(1 mark)

5 (f) Ammonia reacts with nitric acid as shown in this equation.

$$NH_3 + HNO_3 \longrightarrow NH_4NO_3$$

Deduce the type of reaction occurring.

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(1 mark)

14

outside the box

6 Phosphoric(V) acid (H_3PO_4) is an important chemical. It can be made by two methods. The first method is a two-step process.

6 (a) In the first step of the first method, phosphorus is burned in air at 500 ºC to produce gaseous phosphorus(V) oxide.

$$P_4(s) + 5O_2(g) \longrightarrow P_4O_{10}(g)$$

220 g of phosphorus were reacted with an excess of air.

Calculate the volume, in m^3, of gaseous phosphorus(V) oxide produced at a pressure of 101 kPa and a temperature of 500 ºC.
The gas constant $R = 8.31$ J K^{-1} mol^{-1}
Give your answer to 3 significant figures.

[4 marks]

6 (b) In the second step of the first method, phosphorus(V) oxide reacts with water to form phosphoric(V) acid.

$$P_4O_{10}(s) + 6H_2O(l) \longrightarrow 4H_3PO_4(aq)$$

Calculate the mass of phosphorus(V) oxide required to produce 3.00 m^3 of 5.00 mol dm^{-3} phosphoric(V) acid solution.

[3 marks]

outside the box

6 (c) In the second method to produce phosphoric(V) acid, 3.50 kg of $Ca_3(PO_4)_2$ are added to an excess of aqueous sulfuric acid.

$$Ca_3(PO_4)_2(s) + 3H_2SO_4(aq) \longrightarrow 2H_3PO_4(aq) + 3CaSO_4(s)$$

1.09 kg of phosphoric(V) acid are produced.

Calculate the percentage yield of phosphoric(V) acid.

[4 marks]

6 (d) Explain whether the first method or the second method of production of phosphoric acid has the higher atom economy.
You are not required to do a calculation.

[1 mark]

12

END OF QUESTIONS

Answer **all** the questions.

1 Tin mining was common practice on Dartmoor in pre-Roman times. Most of the tin extracted was mixed with copper to produce bronze.

(a) The table below shows the sub-atomic particles of an isotope of tin.

isotope	protons	neutrons	electrons
^{118}Sn			

(i) Complete the table. **[1]**

(ii) In terms of sub-atomic particles, how would atoms of ^{120}Sn differ from atoms of ^{118}Sn?

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

(b) The relative atomic mass of tin is 118.7.

Define the term *relative atomic mass*.

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

(c) A bronze-age shield found on Dartmoor contained 2.08 kg of tin.

Calculate the number of tin atoms in this bronze shield.
Give your answer to **three** significant figures.

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

(d) Tin ore, known as cassiterite, contains an oxide of tin. This oxide contains 78.8% tin by mass. Calculate the empirical formula of this oxide. You must show your working.

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

[Total: 9]