Australian Islamic College 2020

ATAR Chemistry Units 3 and 4

Task 8D (Weighting: 4%)

Stoichiometry and Limiting Reagents Test

Test Time: 40 minutes

Please do not turn this page until instructed to do so.

First Name	Surname
ANSWERS	

Teacher

Mark / 33	Percentage

Equipment allowed: Pens, pencils, erasers, whiteout, correction tape, rulers and non-programmable calculators permitted by the Schools Curriculum and Standards Authority.

Special conditions:

2 marks will be deducted for failing to write your full name on this test paper.

Teacher help: Your teacher can only help you during your test in one situation.

If you believe there is a mistake in a question show your teacher and your teacher will tell you if there is a mistake in the question and if appropriate, how to fix that mistake.

Spelling of Science words must be correct. Unless otherwise indicated, science words with more than one letter wrong (wrong letter and/or wrong place) will be marked wrong. The spelling of IUPAC names must be exactly correct.

Unless otherwise stated, **equations** must be written balanced and with correct state symbols or they will be marked wrong.

In calculations, give answers to the appropriate number of significant figures.

Questions must be answered in this booklet.

Follow-on marks will not be awarded.

Total marks: 33

1. In some countries a flocculating agent is used to help remove very fine suspended solids from domestic water supplies. Aluminium hydroxide, a gelatinous precipitate, is often used as the flocculating agent. As the precipitate settles to the bottom of the sedimentation tank, it carries most of the suspended matter with it. The aluminium hydroxide is formed within the tank by adding aluminium sulfate and calcium hydroxide to the cloudy drinking water. In this process, it is vital that these two substances are mixed in the correct proportions to prevent any health issues that may arise if too much aluminium (in the form of ions) remains dissolved in the drinking water.

   a. Write an ionic equation for the production of aluminium hydroxide in the sedimentation tanks.

   (1 mark)

   $Al^{3+}_{(aq)} + 3OH^{-}_{(aq)} \rightarrow Al(OH)_{3(s)}$

   b. Without knowing any better, a worker added 22.4 tonnes each of aluminium sulfate and calcium hydroxide to a 2.57 ML sedimentation tank.

      i. Which of the two reactants is in excess?

      (5 marks)

      $Al_2(SO_4)_3 + 3Ca(OH)_2 \rightarrow 2Al(OH)_3 + 3CaSO_4$

      $n(Al_2(SO_4)_3) = \frac{m}{M} = \frac{22400000}{342.17} = 65464.535$ mol

      (1)

      $n(Ca(OH)_2) = \frac{m}{M} = \frac{22400000}{74.096} = 302310.516$ mol

      (1)

      AMR = $\frac{Ca(OH)2}{Al2(SO4)3} = \frac{302310.516}{65464.535} = 4.6179$

      (1)

      SR = $\frac{Ca(OH)2}{Al2(SO4)3} = \frac{3}{1} = 3$

      (1)

      AMR > SR therefore
      excess reagent is $Ca(OH)_2$ **(1)**
      (OK to instead state $Al_2(SO_4)_3$ is limiting reagent.)

   Students may use any logical method to calculate limiting reagent but calculations must be shown.
   Final mark cannot be awarded unless all other marks have been awarded.

ii. What mass, in tonnes, of aluminium hydroxide will form in the precipitation reaction?

(3 marks)

$Al_2(SO_4)_3 + 3Ca(OH)_2 \rightarrow 2Al(OH)_3 + 3CaSO_4$
$n(Al_2(SO_4)_3) = 65464.535$ mol
SR = $\frac{2}{1}$ = 2
$n(Al(OH)_2) = 2 \times n(Al_2(SO_4)_3)$
$= 2 \times 65464.535$
$= 130929.07$ mol

(1)

$m(Al(OH)_2) = nM$
$= 130929.07 \times 78.004$
$= 10.2$ tonne (3SF)

(1 for answer, 1 for SF)

2. Monomethyl hydrazine is a commonly used rocket fuel. It has the formula $CH_3(NH)NH_2$, and is often used in combination with dinitrogen tetroxide, N_2O_4, as oxidant. The reaction between monomethyl hydrazine and dinitrogen tetroxide is shown below.

$$4CH_3(NH)NH_{2\,(g)} + 5N_2O_{4\,(g)} \rightarrow 12H_2O_{(g)} + 9N_{2\,(g)} + 4CO_{2\,(g)} + 4742 \text{ kJ}$$

At lift-off, Space Shuttle Star Truck carries 10.1 tonnes of $CH_3(NH)NH_2$ and 16.0 tonnes of slightly impure N_2O_4 in its external tanks. An anticorrosive agent is often added to the oxidant mix. In the case of Star Truck, a solution of HF is added to the N_2O_4 so that the final 16.0 tonnes of oxidant mixture contains 1.50% H_2O by mass and 0.600% HF by mass.

a. Determine which is the limiting reagent in the combustion reaction. Show your reasoning.

(6 marks)

$M(CH_3(NH)NH_2)$ = 46.078 g mol^{-1} **(1)**

$n(CH_3(NH)NH_2)$ = = $\frac{m}{M}$ **=** $\frac{10100000}{46.078}$ **= 219193.54 mol** **(1)**

$M(N_2O_4)$ = 92.02 g mol^{-1} **(1)**

$n(N_2O_4)$ = = $\frac{m}{M}$ **=** $\frac{16000000}{92.02}$ **x 0.979 = 170223.86 mol** **(1)**

AMR = $\frac{CH3(NH)NH2}{N2O4}$ **=** $\frac{219193.54}{170223.86}$ **= 1.287**

SR = $\frac{CH3(NH)NH2}{N2O4}$ **=** $\frac{4}{5}$ **= 0.8** **(1)**

AMR > SR therefore N_2O_4 is the limiting reagent. **(1)**

Any logical way of determining limiting reagent is OK but calculations must be shown.

The last mark cannot be awarded unless all the other marks have been awarded.

b. Determine the total volume of gas produced from the combustion of the entire propellant mixture when measured at STP.

(4 marks)

Description	Marks
At STP, H_2O is not a gas, $\therefore$ n(gas) produced from 5 mol N_2O_4 = 9 mol N_2 + 4 mol CO_2 = 13 mol gas	1
i.e., 5 mol N_2O_4 produces 13 mol gas 1.7022386×10^5 mol produces X $X = (13 \times 1.7022386 \times 10^5)/5 = 4.425 \times 10^5$ mol gas	1
At STP: $V = n \times 22.71 = 4.4258202 \times 10^5 \times 22.71 = 1.00 \times 10^7$ L	1
Total	**3**

No marks are possible if student's calculation assume water is a gas.
1 mark for correct significant figures. Significant figure mark can be awarded even if answer is wrong.

c. The combustion chamber of Star Truck is at very high pressure and temperature to generate thrust and allow lift-off as the exhaust gases are expelled. At full thrust, the chamber is at a pressure of 2.03×10^4 kPa and temperature 3.30×10^3 °C. The chamber is designed to hold, at any one time, 0.05% by volume of the total gas produced. Determine the volume of the combustion chamber.

(4 marks)

Description	Marks
Total gas produced **at high temp (H_2O is a gas):** 5 mol N_2O_4 produces 25 mol gas	1
i.e., 5 mol N_2O_4 produces 25 mol gas 1.702336×10^5 mol produces X $X = (25 \times 1.702336 \times 10^5)/5 = 8.511 \times 10^5$ mol gas (total) produced	1
Tank holds 0.05 % of total gas produced = $0.0005 \times 8.51168 \times 10^5$ = 425.58 mol gas	1
PV = nRT V = (nRT)/P = $\dfrac{425.584 \times 8.314 \times (3300 + 273.15)}{2.03 \times 10^4} = 622.77 = 623$ L	1
Total	**4**

1 mark off any awarded marks if significant figures are wrong.

3. An engineer working on the Apollo missions noticed that one of the fuel cells that was to be used in the Lunar Module was leaking potassium hydroxide. The potassium hydroxide was dripping from the cell and forming a puddle on the warehouse floor. He knew the concentration of potassium hydroxide used in the cell should be 400.0 g L^{-1} and he estimated the size of the puddle to be 1.5 L in volume. The engineer found some 2.75 mol L^{-1} sulfuric acid solution, $H_2SO_{4(aq)}$, in the storeroom and poured 1.9 L of this onto the $KOH_{(aq)}$ in order to neutralise the spill.

   The neutralisation reaction that took place is as follows;

$$2KOH_{(aq)} \quad + \quad H_2SO_{4(aq)} \quad \rightarrow \quad K_2SO_{4(aq)} \quad + \quad 2H_2O_{(l)}$$

   a. Based on the engineer's estimations, determine the limiting reagent. (5 marks)

n(KOH in 400 g) = 400 / 56.108

= 7.129108 mol

i.e. c(KOH) = 7.129 mol L^{-1}

n(KOH) = cV = 7.129108 x 1.5 = 10.69366 mol **(1)**

n(H_2SO_4) = cV = 2.75 x 1.9 = 5.225 mol **(1)**

SR of KOH:H_2SO_4 is 2:1 = 2 **(1)**

AMR of KOH:H_2SO_4 is 10.69366: 5.225 = 2.0466 **(1)**

AMR > SR therefore H_2SO_4 is limiting reagent **(1)**

Final mark cannot be awarded unless all other marks have been awarded.

b. Based on the engineer's estimations, calculate the final pH of the puddle and state whether the spill has been effectively neutralised.

(5 marks)

n(xs KOH)	**=**	**10.69366 - 10.45**	
	=	**0.24366 mol**	**(1)**
c(xs KOH)	**=**	**n/V**	
	=	**0.24366 / 3.4**	
	=	**0.0716647 mol L^{-1}**	**(1)**
$[H^+]$	**=**	**1.0 x 10^{-14} / $[OH^-]$**	
	=	**1.0 x 10^{-14} / 0.0716647**	
	=	**1.39539 x 10^{-13} mol L^{-1}**	**(1)**
pH	**=**	**-log$[H^+]$**	
	=	**-log (1.39539 x 10^{-13})**	
	=	**12.86**	
	=	**13**	**(1)**

i.e. no, the spill has not been neutralised **(1)**

This mark cannot be awarded unless all previous marks have been awarded.

1 mark off for wrong number of significant figures.

End of Test