Australian Islamic College 2019

ATAR Chemistry Units 3 and 4

Task 13 (Weighting: 3%)

Calculations Test

Test Time: 45 minutes

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

First Name	Surname
ANSWERS	

Teacher

Mark / 39	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. Science words with more than one letter wrong (wrong letter and/or wrong place) will be marked wrong.

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

Questions must be answered in this booklet.

Total marks: 39

Note that in this test 'follow-on' marks will not be awarded.

Final answers should be given to the appropriate number of significant figures. Correct units should be given in final answers.

<u>Special note: In empirical formula calculations, a tolerance of 0.1 should be used when rounding mole ratios to whole numbers.</u>

For all questions, 1 mark off for significant figures and/or unit wrong.

Answer all questions. Write your answers in the spaces provided.

1. An experiment was carried out to determine the amount of calcium present in a sample of seashells collected on City Beach in Perth. 15.65 g of the shells were crushed and then added to excess 2.00 mol L^{-1} hydrochloric acid. The resulting solution was filtered. Approximately 350 mL of 1.0 mol L^{-1} oxalic acid was added to the filtrate, which resulted in a precipitate of calcium oxalate (CaC_2O_4). When dried, this precipitate had a mass of 9.65 g.

   (a) Calculate the % (by mass) of calcium carbonate present in the seashells.

   [4 marks]

   $n(CaC_2O_4) = m/M = 9.65 / 128.1 = 0.07533$ mol **[1]**

   $n(Ca) = 0.07533$ mol

   $n(CaCO_3) = 0.07533$ mol **[1]**

   $m(CaCO_3) = 0.07533 \times 100.09 = 7.540$ g **[1]**

   $\%(Ca) = (7.540 / 15.65) \times 100 = 48\%$ **[1]**

   (b) Calculate the minimum volume (in mL) of the hydrochloric acid required in the first stage of the process.

   [3 marks]

   $CaCO_3 + 2HCl \rightarrow CaCl_2 + CO_2 + H_2O$

   $n(HCl) = (2 / 1) \times n(CaCO_3) = (2 / 1) \times 0.07533$ **[1]**

   $= 0.1507$ mol

   $V(HCl) = n / c = 0.1507 / 2.00$ **[1]**

   $= 0.07533$ L $= 75$ mL **[1]**

2. The fertiliser superphosphate, calcium dihydrogen phosphate ($Ca(H_2PO_4)_2$), was mined for many years on the Pacific island of Nauru. Phosphorus is an essential nutrient to animals and plants. The fertiliser is now manufactured industrially by reacting sulfuric acid (H_2SO_4) with calcium phosphate "rock phosphate", ($Ca_3(PO_4)_2$).

$Ca_3(PO_4)_{2(s)} + H_2SO_{4(aq)} \rightarrow Ca(H_2PO_4)_{2(s)} + CaSO_{4(s)}$ [*unbalanced*]

(a) Write a balanced chemical equation for this process.

[1 mark]

$Ca_3(PO_4)_{2(s)} + 2H_2SO_{4(aq)} \rightarrow Ca(H_2PO_4)_{2(s)} + 2CaSO_{4(s)}$ [1]

In a given day a reactor combines 35 000 kg of impure rock phosphate (75.0% purity, by mass) with 15 000 L of 18.0 M H_2SO_4.

(b) Determine which reactant is the limiting reagent.

[4 marks]

$m(Ca_3(PO_4)_2)_{pure}$ = 0.750 x 35 000 = 26 250 kg [1]

$n(Ca_3(PO_4)_2)_{pure}$ = 26 250 x 1000 / 310.18 = 84 628 mol [1]

$n(H_2SO_4)$ = 18.0 x 15 000 = 270 000 mol [1]

$n(Ca_3(PO_4)_{2(s)})_{required} = ½ \times n(H_2SO_{4(aq)})_{required}$

Stoichiometric ratio is: 1:2 and actual mole ratio is approx. 1:3.2
Therefore LR is $Ca_3(PO_4)_2$ [1]

Final mark can only be given if number of moles of both reactants has been calculated correctly and if equation is correctly balanced i.e. no mark for lucky guesses of LR.

(c) Determine the mass in tonnes of excess reactant remaining after the reaction.

[2 marks]

$n(H_2SO_4)_{excess}$ = 270 000 – 2(84 628) = 100 743 mol [1]

$m(H_2SO_4)_{excess}$ = 100 743 x 98.076 = 9.88×10^6 g
= 9.9 tonnes [1]

(d) What mass of superphosphate (in tonnes) would be produced, if the conversion process is 80.0 % efficient?

[2 marks]

$n(Ca(H_2PO_4)_2(s))_{produced}$ = $n(Ca_3(PO_4)_2(s))_{reacted}$

$n(Ca(H_2PO_4)_2(s))_{produced}$ (if 80.0% efficient) = 0.80 x 84 628

= 67 702.6 mol [1]

$m(Ca(H_2PO_4)_2(s))_{produced}$ (if 80.0% efficient) = 67 702.6 x 234.052 g

= 16 tonnes [1]

3. Chocolate is made from the seeds of a plant called *Theobroma cacao*. Chocolate contains many compounds, including the bitter alkaline substance, theobromine. It is found in the cacao plant and is a water insoluble, crystalline white solid.

   The compound theobromine contains the elements carbon, hydrogen, nitrogen and oxygen.

   The complete combustion of 3.22 g of the compound released 5.51 g of carbon dioxide and 1.28 g of water.

   Further testing of 1.68 g of the compound converted all its nitrogen to NO_2 gas. This gas occupied a volume of 1.12 L, at 100^{o}C and 103 kPa pressure.

(a) Determine the empirical formula of theobromine.

[8 marks]

$m(C)_{in\ 3.22\ g}$ = 12.01 / 44.01 x 5.51 g = 1.504 g

%(C) = 1.504 / 3.22 g x 100% = 46.70% **[1]**

$m(H)_{in\ 3.22\ g}$ = 2 x 1.008 / 18.016 x 1.28 g = 0.1432 g

%(H) = 0.1432 / 3.22 x 100% = 4.45% **[1]**

$n(NO_2)$ = PV / RT = 103 x 1.12 / (8.315 x 373)

= 0.03719 mol **[1]**

$m(N)_{in\ 1.68\ g}$ = 0.03719 x 14.01 = 0.5211 g

%(N) = 0.5211 / 1.68 x 100% = 31.02% **[1]**

%(O) = 100 – (46.70 + 4.45 + 31.02) = 17.83% **[1]**

C	H	N	O
46.70 / 12.01	4.45 / 1.008	31.02 / 14.01	17.83 / 16.00
3.888	4.419	2.214	1.114 **[1]**
3.888 / 1.114	4.419 / 1.114	2.214 / 1.114	1.114 / 1.114 **[1]**
3.49	3.97	1.99	1.00

Therefore EF (theobromine) = $C_7H_8N_4O_2$ **[1]**

No marks for correct EF if calculations do not lead to that answer.

(b) Analysis of the compound indicates that its relative molecular mass is approx.180. Determine its molecular formula.

[2 marks]

M(EF) = (7 x 12.01) + (8 x 1.008) + (4 x 14.01) + (2 x 16.00)

= 180.174 **[1]**

Therefore the EF = MF i.e. MF (theobromine) = $C_7H_8N_4O_2$ **[1]**

(c) Theobromine is toxic to dogs. The toxicity level is 300 mg per kg of dog. How much chocolate would an 8.00 kg dog need to consume to poison itself if a particular brand of chocolate on offer contains 2.50 % (by mass) theobromine?

[2 marks]

Toxicity level (for 8.00 kg dog) = 8.00 x 300 mg

= 2400 mg

= 2.40 g theobromine **[1]**

Mass of brand chocolate = 2.40 x (100 / 2.50)

= 100 g **[1]**

4. Amino acids contain one or more amine groups and one or more carboxylic acid groups. A particular diprotic amino acid, Amino Acid X, which contains carbon, hydrogen, oxygen and nitrogen, underwent analysis to determine its formula. When a 5.00 g sample of Amino Acid X was combusted in oxygen, 7.48 g of carbon dioxide and 2.77 g of water was produced. A separate 3.00 g sample produced 0.938 g of nitrogen dioxide when burnt in oxygen.

   4.56 g of Amino Acid X was dissolved in 100.0 mL of water. 20.0 mL of this solution required 24.8 mL of 0.500 mol L^{-1} sodium hydroxide for complete neutralisation.

   (a) Calculate the molecular mass of Amino Acid X.

   [4 marks]

   n(NaOH) = c x V = 0.500 x 0.0248 = 0.0124 mol **[1]**

   n(Amino Acid X) in 20 mL = (1 / 2) x n(NaOH) = 0.00620 mol **[1]**

   n(Amino Acid X) in 100 mL = (100 / 20) x 0.00620 = 0.0310 mol **[1]**

   using n = m / M M = m / n = 4.56 / 0.0310 = 147 g mol^{-1} **[1]**

(b) Calculate the empirical formula of Amino Acid X.

[7 marks]

m(C) in 5.00 g = (12.01/ 44.01) x 7.48 = 2.041 g

% (C) = (2.041 / 5.00) x 100 = 40.82% **[1]**

m(H) in 5.00 g = (2.016/ 18.016) x 2.77 = 0.3099 g

% (H) = (0.3099 / 5.00) x 100 = 6.20% **[1]**

m(N)in 3.00 g = (14.01 / 46.01) x 0.938 = 0.286 g

% (N) = (0.286 / 3.00) x 100 = 9.52% **[1]**

% (O) = 100 – 40.8 – 6.2 – 9.5 = 43.5% **[1]**

C	**H**	**N**	**O**	
40.8 %	**6.2%**	**9.5 %**	**43.5%**	
40.8 / 12.01	**6.2 / 1.008**	**9.5 / 14.01**	**43.5 / 16.00**	**[1]**
3.397	**6.15**	**0.678**	**2.719**	
3.397 / 0.678	**6.15 / 0.678**	**0.678 / 0.678**	**2.719 / 0.678**	**[1]**
5.01	**9.07**	**1.00**	**4.01**	
5	**9**	**1**	**4**	

Empirical Formula is $C_5H_9NO_4$ **[1]**

END OF TEST

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