Chemistry

Unit 4

Area of Study 4 Test:

Industrial chemistry

This sample test paper has been prepared as part of the Pearson suite of resources for the Year 12, Unit 4, ATAR Chemistry Course prescribed by the Western Australian School Curriculum and Standards Authority.

Time allowed

Reading time: 5 minutes Working time: 45 minutes

Materials required

An approved non-programmable calculator.

Chemistry Data Booklet. This may be downloaded from the SCSA website.

Structure of this paper

Section	Number of questions available	Number of questions to be answered	Suggested working time (minutes)	Marks available	Percentage of total test
Section 1: Multiple choice	6	6	12	12	27
Section 2: Short answer	3	3	14	14	31
Section 3: Extended answer	2	2	19	19	42
		Total	**45**	**45**	**100**

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Section 1: Multiple choice 27% (12 marks)

This section has **6** questions. Answer **all** questions by circling the correct option. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

Suggested working time: 12 minutes

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1 In the following reaction, 4 moles of aluminium are added to a solution containing 6 moles of hydrochloric acid (HCl):

$$2Al(s) + 6HCl(aq) \rightarrow 2\ AlCl_3(aq) + 3H_2(g)$$

Assuming the reaction goes to completion, select the correct statement below:

A Al is the limiting reagent and 3 moles of H_2 gas are produced.

B Al is the limiting reagent and 6 moles of H_2 gas are produced.

C HCl is the limiting reagent and 3 moles of H_2 gas are produced.

D HCl is the limiting reagent and 6 moles of H_2 gas are produced.

2 Ammonia can be produced according to the following equation:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

The reaction as written is exothermic.

Which of the following changes will increase the amount of ammonia at equilibrium?

I adding a finely divided catalyst

II increasing the partial pressure of the gases

III increasing the temperature in the reaction vessel

A I only

B II only

C I and II only

D II and III only

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Questions 3 and 4 refer to the following information.

Nitric acid (HNO_3) is an important industrial chemical. The synthesis of nitric acid involves the oxidation of nitrogen. However, the direct oxidation of atmospheric nitrogen produces a very small percentage yield. A less direct, but more successful, reaction sequence is outlined below.

I $4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g)$ $\Delta H < 0$

II $2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$ $\Delta H < 0$

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

3 Reaction I is slow at room temperature. To increase the reaction rate to an acceptable level, a finely divided catalyst is used and the temperature raised to about 900°C. Which one of the following alternatives correctly describes why a catalyst and an increase in temperature increase the reaction rate?

	Catalyst	**Increase in temperature**
A	increases the activation energy of the reaction	increases the activation energy of the reaction
B	decreases the activation energy of the reaction	decreases the activation energy of the reaction
C	increases the average energy of molecules so that a higher proportion collide successfully	increases the energy required for molecules to collide successfully
D	decreases the energy required for molecules to collide successfully	increases the average energy of molecules so that a higher proportion collide successfully

4 Which one of the following combinations of temperature and pressure would result in the highest equilibrium yield of $NO_2(g)$ in reaction II?

	Temperature (°C)	**Pressure (kPa)**
A	30	100
B	30	300
C	300	100
D	300	300

Questions 5 and 6 refer to the following reaction, which forms part of the Contact process.

$$2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$$

5 If at constant temperature and pressure, 8.2 kL of SO_2 are mixed with 6 kL of O_2, 3.8 kL of SO_3 are produced. Given this information, calculate the percentage efficiency of the process.

A 92.7%

B 73.2%

C 63.3%

D 46.3%

6 In practice, for this step in the Contact process, sulfur dioxide and oxygen are usually mixed together in a 1:1 molar ratio, despite their 2:1 stoichiometric ratio in the equation. Select the statement below that correctly describes the reason for this.

A Sulfur dioxide is heavier than oxygen, so its molecules have a lower velocity than the molecules of oxygen gas.

B An excess of oxygen is used to drive the equilibrium position to the right, favouring the formation of sulfur trioxide.

C An excess of oxygen is required as it also reacts with other impurities in the reaction vessel.

D Although the frequency of collisions between oxygen and sulfur dioxide remains constant, using an excess of oxygen increases the proportion of collisions that are successful.

End of section 1

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Section 2: Short answer 31% (14 marks)

This section has **3** questions. Answer **all** questions. Write your answers in the space provided.

When calculating numerical answers, show your working or reasoning clearly. Express numerical answers to the appropriate number of significant figures and include appropriate units where applicable.

Do not use abbreviations, such as 'nr' for 'no reaction', without first defining them.

Suggested working time: 14 minutes

Question 7 **(4 marks)**

In the Haber process, ammonia is produced according to the following reaction:

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

When the gases leave the reactor, they are hot and at a very high pressure. Ammonia can be separated from any unreacted N_2 and H_2 gases by lowering the temperature.

Using your knowledge of intermolecular forces, explain how this separation occurs:

Question 8 **(5 marks)**

4.00 g of magnesium is reacted with an excess of oxygen gas to produce 5.69 g of magnesium oxide.

a Write a balanced equation to represent this reaction. (1 mark)

b Determine the percentage yield for this reaction. (4 marks)

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Question 9 **(5 marks)**

The production of potassium perchlorate, $KClO_4$, follows the following series of reactions, with Step 1 being only 70% efficient:

Step 1: $Cl_2(g) + 2KOH(aq) \rightarrow KCl(aq) + KClO(aq) + H_2O(l)$ 70% efficient

Step 2: $3KClO(aq) \rightarrow 2KCl(aq) + KClO_3(aq)$

Step 3: $4KClO_3(aq) \rightarrow KCl(aq) + 3KClO_4(aq)$

Calculate the volume of Cl_2 (measured at 40°C and 120 kPa) required to produce 1.00 tonne (1000 kg) of potassium perchlorate, assuming that all other reactants are in excess.

End of section 2

Section 3: Extended answer 42% (19 marks)

This section has **2** questions. Answer **both** questions. Write your answers in the space provided.

When calculating numerical answers, show your working or reasoning clearly. Express numerical answers to the appropriate number of significant figures and include appropriate units where applicable.

Do not use abbreviations, such as 'nr' for 'no reaction', without first defining them.

Suggested working time: 19 minutes

Question 10 **(12 marks)**

In the Contact Process, sulfuric acid is manufactured in stages from sulfur dioxide. The overall process can be summarised as follows:

Step 1: Sulfur dioxide is produced from the combustion of sulfur

Step 2: Sulfur dioxide is oxidised by oxygen to form sulfur trioxide

Step 3: Sulfur trioxide dissolves in sulfuric acid to form oleum ($H_2S_2O_7$)

Step 4: Oleum is mixed with water to form sulfuric acid

a Write equations to represent each of the reactions described above: (4 marks)

Step 1: _____

Step 2: _____

Step 3: _____

Step 4: _____

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b The reaction described in step 2 is an equilibrium step, with a ΔH value of –197 kJ. In practice, this reaction is carried out at a moderate temperature of 400–500˚C and at atmospheric pressure. With reference to both rate and yield and relevant chemical theories, describe why these conditions are used. (8 marks)

Question 11 **(7 marks)**

Iron pyrite (FeS_2) is a compound found in soils below the water table. It reacts with the oxygen in the air and water to form sulfuric acid and iron (III) hydroxide according to the following equation:

$$4FeS_2(s) + 15O_2(g) + 14H_2O(l) \rightarrow 8H_2SO_4(aq) + 4Fe(OH)_3(s)$$

A 2.93 g sample of iron pyrite was taken for analysis and reacted with 2.0 L of oxygen (measured at STP) in the presence of excess water.

a Determine the limiting reagent. (4 marks)

b Determine the mass of iron(III) hydroxide produced from this reaction. (3 marks)

End of questions

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