Chemistry

Unit 3

Area of Study 1 Test:

Dynamic equilibrium systems

This sample test paper has been prepared as part of the Pearson suite of resources for the Year 12, Unit 3, 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	8	8	13	16	23
Section 2: Short answer	4	4	21	28	41
Section 3: Extended answer	2	2	11	25	36
		Total	**45**	**69**	**100**

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Section 1: Multiple choice 23% (16 marks)

This section has **8** 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: 13 minutes

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1 Which one of the following is the equilibrium law expression for the reaction below?

$$Pb^{2+}(aq) + 2Br^{-}(aq) \rightleftharpoons PbBr_2(s)$$

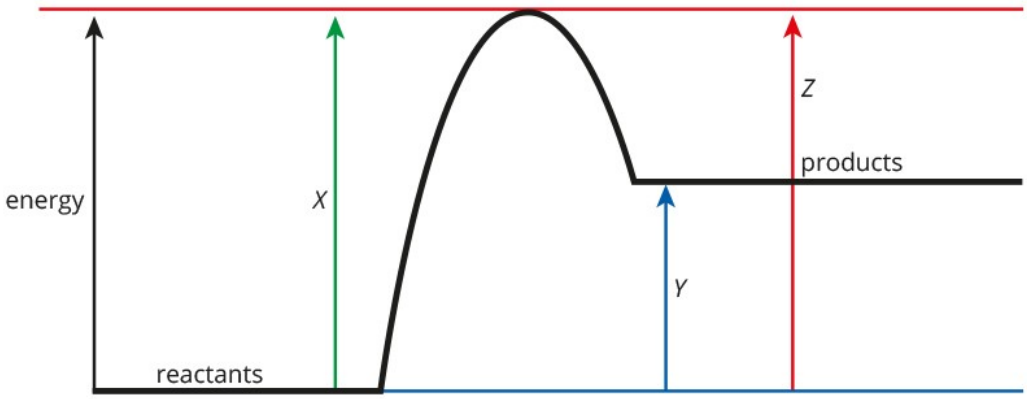
A $\dfrac{[PbBr_2(s)]}{[Pb^{2+}(aq)][2Br^{-}(aq)]}$

B $\dfrac{1}{[Pb^{2+}(aq)][Br^{-}(aq)]^2}$

C $[Pb^{2+}(aq)][Br^{-}(aq)]^2$

D $\dfrac{[Pb^{2+}(aq)][Br^{-}(aq)]^2}{[PbBr_2(s)]}$

2 Consider the following energy level diagram.



The effect of a catalyst on this reaction would be to change which one of the following values?

A *X* only

B *Y* only

C *X* and *Z* only

D *X*, *Y* and *Z*

3 One of the steps in the production of sulfuric acid involves the oxidation of sulfur dioxide to sulfur trioxide according to the following equation.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \quad \Delta H < 0$$

Which one of the following changes will increase the amount of $SO_3(g)$ at equilibrium?

I increasing the temperature at constant volume

II decreasing the volume of the reaction vessel at constant temperature

III adding a catalyst at constant temperature

A I only

B II only

C I and III only

D II and III only

4 Nitrogen gas, $N_2(g)$, can react with oxygen gas, $O_2(g)$, to form nitrogen(II) oxide, $NO(g)$. In a closed system, all three gases exist in equilibrium. The equation for this reaction is:

$$N_2(g) + O_2(g) \rightleftharpoons 2NO(g) \qquad \Delta H = +181 \text{ kJ}$$

Which of the following changes, at constant temperature, will **initially** increase the rate of the forward reaction but not that of the reverse reaction?

I increasing the partial pressure of $O_2(g)$

II decreasing the partial pressure of $NO(g)$

III decreasing the volume of the reaction vessel

A I only

B II only

C II and III only

D I and II only

5 The value of the equilibrium constant for the equilibrium:

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$

is 160 at a temperature of 500 K and 54 at a temperature of 700 K. What can we deduce from this data?

A The forward reaction is exothermic.

B The reaction is faster at 500 K than at 700 K.

C The activation energy of the forward reaction is greater than the activation energy for the reverse reaction at both temperatures.

D The concentration of $I_2(g)$ in the equilibrium mixture will be higher at 500 K than at 700 K.

6 Ammonia can be produced from nitrogen and hydrogen as follows:

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

In the industrial production of ammonia, an iron oxide catalyst is used. What does this increase?

A the rate of the forward reaction only

B the rate of the forward and reverse reactions equally

C activation energy of the forward and reverse reactions equally

D activation energy of the forward reaction more than the rate of the reverse reaction.

7 In which one of the following equilibrium systems would the formation of products be favoured when the pressure is lowered at constant temperature?

A $2CO(g) \rightleftharpoons 2C(s) + O_2(g)$

B $PCl_3(g) + Cl_2(g) \rightleftharpoons PCl_5(g)$

C $N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$

D $COBr_2(g) \rightleftharpoons CO(g) + Br_2(g)$

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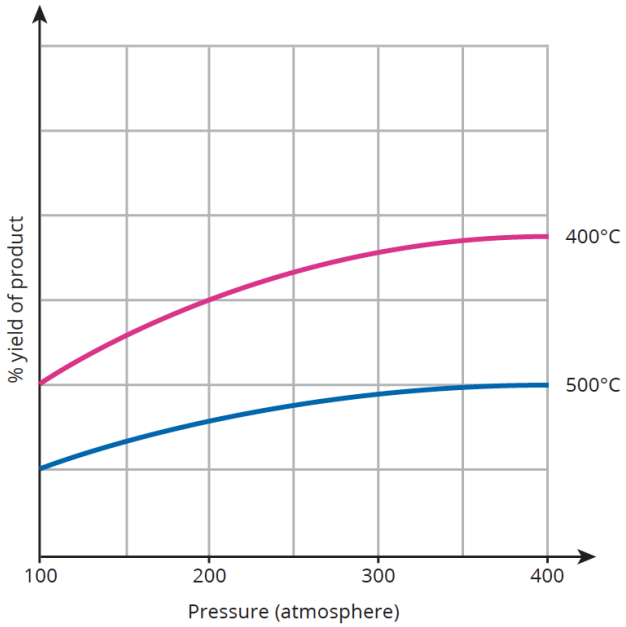
8 The percentage yield of a particular equilibrium reaction has been studied at different temperatures and pressures. Some of the results are shown below.



Which one of the following equilibrium systems would be expected to give the above results?

A $2NO_2(g) \rightleftharpoons O_2(g) + 2NO(g)$ $\Delta H > 0$

B $3H_2(g) + CO(g) \rightleftharpoons H_2O(g) + CH_4(g)$ $\Delta H > 0$

C $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ $\Delta H < 0$

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

End of section 1

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Section 2: Short answer 41% (28 marks)

This section has **4** 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 three 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: 21 minutes

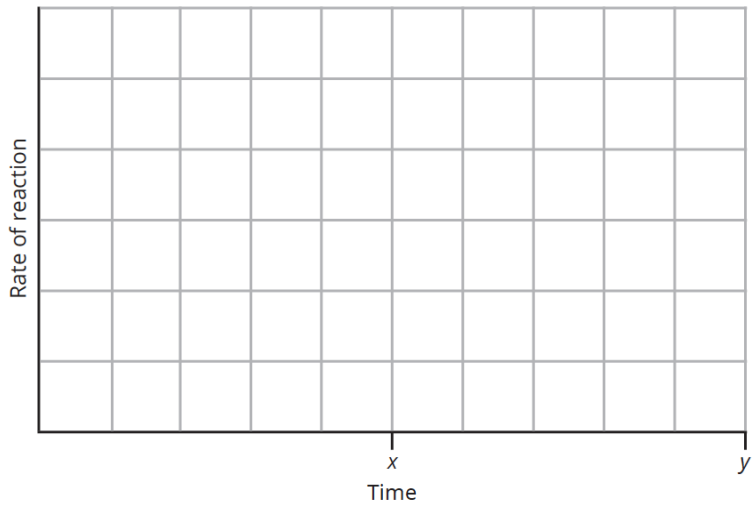
Question 9 **(9 marks)**

Some carbon dioxide and hydrogen gas are placed in an empty container and heated to 2000 K. The following equilibrium is established:

$$CO_2(g) + H_2(g) \rightleftharpoons CO(g) + H_2O(g)$$

a On the axes below, sketch a graph to show how the rate of the forward and reverse reactions change with time as the system approaches and reaches equilibrium at time *x*. Continue your graph to time *y* to indicate the rate of forward and reverse reactions at equilibrium.

Clearly label the forward and reverse reactions. (4 marks)



b The temperature of the equilibrium mixture is maintained at 2000 K but the volume of the vessel is doubled. Explain why there is no resultant change in the equilibrium amounts of reactants and products in terms of:

i the equilibrium law expression (3 marks)

ii reaction rates (2 marks)

Question 10 **(5 marks)**

a Bottled soda water contains dissolved carbon dioxide. In a closed bottle of soda water, the following equilibrium exists:

$$CO_2(g) \rightleftharpoons CO_2(aq)$$

Explain why the system is no longer at equilibrium once the bottle is open. Your answer should discuss reaction rates. (3 marks)

b Carbon dioxide gas also dissolves in the world's oceans. The dissolved carbon dioxide reacts with water to establish the following equilibrium systems:

$$CO_2(aq) + H_2O(l) \rightleftharpoons H_2CO_3(aq) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$$

Explain, in terms of the equilibrium systems involved, why an increasing level of atmospheric carbon dioxide would increase the acidity of the ocean. (2 marks)

Question 11 **(8 marks)**

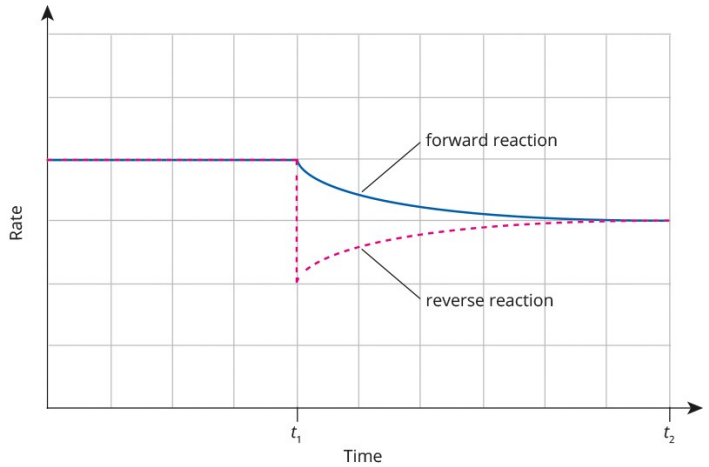
In aqueous solution, the dichromate ion is orange and the chromate ion is yellow. These two ions are in equilibrium:

$$Cr_2O_7^{2-}(aq) + H_2O(l) \rightleftharpoons 2CrO_4^{2-}(aq) + 2H^+(aq)$$

a State two ways in which you could tell that equilibrium had been reached. (2 marks)

b The following graph shows the rate of the forward and reverse reactions for this equilibrium. The temperature is kept constant throughout the experiment. At time t_1 a change, other than a change in amount of $CrO_4^{2-}(aq)$, is imposed on the system.

The system responds to the change and a new equilibrium is reached at t_2.



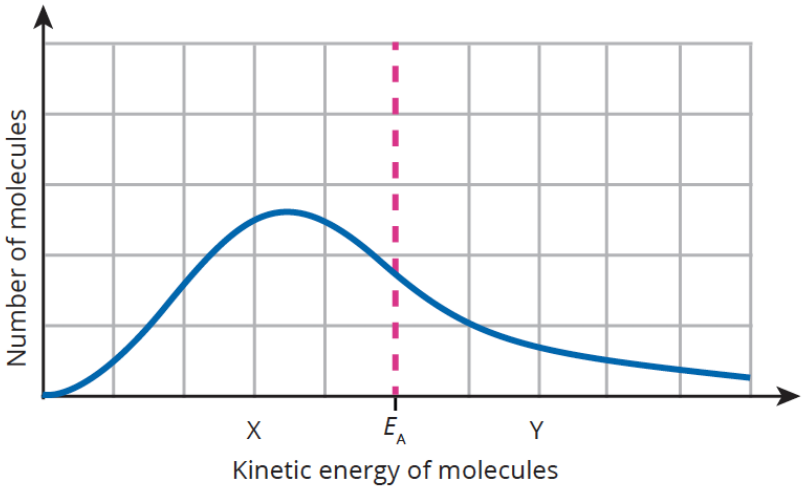
i What could have caused the change at time t_1? (1 mark)

ii Describe how and explain why the colour of the equilibrium mixture at t_2 will differ from that at t_1. Your answer should discuss reaction rates. (3 marks)

iii Will the value of the equilibrium constant at the new equilibrium at t_2 be greater than, the same as or smaller than that at t_1? Justify your choice. (2 marks)

Question 12 **(6 marks)**

The following graph shows the kinetic energy of gas molecules in a reaction mixture at 300 K.



The point E_A represents the activation energy required for an uncatalysed reaction to occur.

a **i** On the above graph, sketch the kinetic energy of the molecules if the temperature was increased. (1 mark)

ii Use your sketched graph to explain why an increase in temperature results in an increase in reaction rate. (2 marks)

b **i** For a catalysed reaction, would the activation energy be more likely to be at X or Y? State a reason for your answer. (2 marks)

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ii Use the graph and your answer above to explain why a catalyst increases the rate of a reaction. (1 mark)

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End of section 2

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Section 3: Extended answer 36% (25 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 three significant figures and include appropriate units where applicable.

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

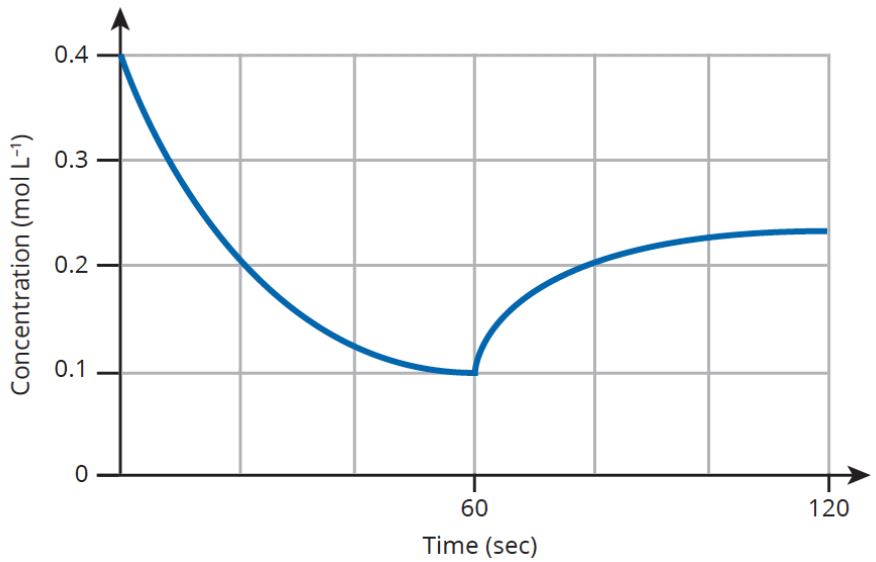
Suggested working time: 11 minutes

Question 13 **(13 marks)**

Nitrogen dioxide, $NO_2(g)$, is a dark brown gas. Two moles of $NO_2(g)$ combine to form the colourless gas dinitrogen tetroxide, $N_2O_4(g)$. These two gases exist at equilibrium as shown in the following equation:

$$2NO_2(g) \rightleftharpoons N_2O_4(g)$$

Some $NO_2(g)$ is placed in an empty gas syringe and allowed to come to equilibrium with $N_2O_4(g)$. The following graph shows the change in concentration of $NO_2(g)$ in the syringe over 60 seconds. At the 60-second mark, the temperature of the system is increased at constant volume.



a Write the equilibrium law expression for this equilibrium system. (1 mark)

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b Describe the colour change that would be observed in the syringe contents over the first 60 seconds. (1 mark)

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c On the above graph, sketch the expected change in concentration of $N_2O_4(g)$ for the first 60 seconds. (2 marks)

d Explain, in terms of rates of the forward and reverse reactions, why the concentration of $NO_2(g)$ in the syringe decreases rapidly at first then remains unchanged from the 55- to the 60-second mark. (4 marks)

e From the information given, deduce whether the formation of $N_2O_4(g)$ from $NO_2(g)$ is an endothermic or exothermic process and explain your reasoning. (2 marks)

f The syringe and contents are returned to room temperature and the plunger of the gas syringe pushed inwards so as to increase the internal pressure.

Provide an explanation for each of the following observations. (4 marks)

Observation	Explanation
As soon as the plunger of the syringe is pushed inwards, the colour of the contents of the syringe becomes significantly darker brown.	
After a few minutes, the colour of contents of the syringe have become paler, but not as pale as before the plunger was pushed inwards.	

Question 14 **(12 marks)**

In the lungs, the exchange of oxygen and carbon dioxide takes place when blood vessels pass around tiny air sacs called alveoli. Oxygen gas in the alveoli dissolves into the blood plasma (which is mostly water) then enters red blood cells while carbon dioxide leaves red blood cells to dissolve in the plasma and then enter the alveoli. The equilibria involved in the exchange between the plasma and alveoli are:

$$O_2(g) \rightleftharpoons O_2(aq)$$

$$CO_2(aq) \rightleftharpoons CO_2(g)$$

a State the conditions, in terms of the O_2 and CO_2 gas pressures, that will favour the uptake of oxygen by the blood and release of carbon dioxide from the blood. Explain your answer with reference to rates of reactions. (4 marks)

Red blood cells contain haemoglobin, Hb, which carry oxygen as oxyhaemoglobin, HbO_2, from the lungs to body cells and carry carbon dioxide as carbaminohaemoglobin, $HbCO_2^-$, from body cells to the lungs. This transport and exchange of gases involves three equilibria that take place in a red blood cell as follows

1 $CO_2(aq) + HbO_2(aq) \rightleftharpoons HbCO_2^- + H^+ + O_2(aq)$

2 $CO_2(aq) + H_2O(l) \rightleftharpoons H_2CO_3(aq) \rightleftharpoons HCO_3^-(aq) + H^+(aq)$

3 $HbO_2(aq) + H^+(aq) \rightleftharpoons H^+Hb(aq) + O_2(aq)$

b For each of the species listed below, state whether its concentration in a red blood cell is at its highest when a red blood cell is just leaving the lungs or when it is just leaving a body cell. (4 marks)

Species	When concentration highest (write 'just leaving lungs' or 'just leaving body cell')
$HbO_2(aq)$	
$HbCO_2^-(aq)$	
$HCO_3^-(aq)$	
$H^+Hb(aq)$	

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c The concentration of $HbO_2(aq)$ in a red blood cell is high when it arrives at a body cell and the concentration of $CO_2(aq)$ is high in the body cell. With reference to the three equilibria shown above, explain how the oxygen is delivered to the body cell from the red blood cell. Your answer needs to discuss rates of reactions. (4 marks)

End of questions

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