ALL SAINTS' COLLEGE

Science Department
Year 12 ATAR Chemistry
Test 2: Equilibrium

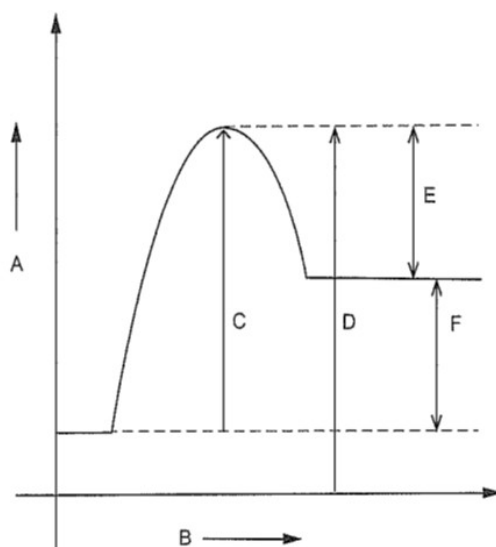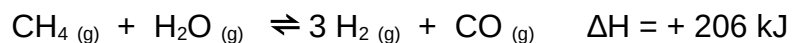Name: _____ **Answers** _____

Teacher: _____

Instructions

1. _____ permitted
2. _____ all questions
3. _____ Write in the spaces provided
4. Show all working when required
5. All answers to be in blue or black pen, diagrams in pencil.

Multiple Choice	Short Answer	TOTAL	Final Percentage
/12	/48	/60	

Questions 1 – 3 refer to the reaction and diagram below:

$$CH_{4\ (g)} + H_2O_{(g)} \rightleftharpoons 3\,H_{2\ (g)} + CO_{(g)} \qquad \Delta H = +\,206\ kJ$$

1.   Which one of the following is true?

a)   The forward reaction is endothermic.
b)   The axis representing potential energy is B.
c)   The enthalpy difference for the reaction is E.
d)   The activation energy for the forward reaction is D minus C.


2.   Which one of the following represents the activation energy for the reverse reaction?

a)   C
b)   D
c)   E
d)   D plus F

3.   Which one of the following represents the heat of reaction for the forward reaction?

a)   C minus D
b)   E
c)   C
d)   F

Enthalpy (H)

3C$_2$H$_2$

656 kJ

C$_6$H$_6$

83 kJ
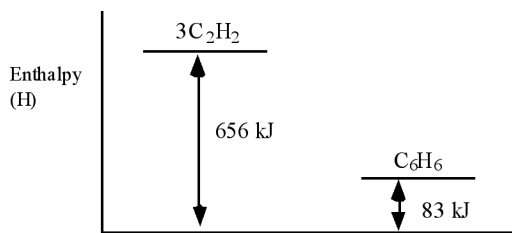
4.   Use the information in the above diagram to calculate ΔH for the reaction
      3C$_2$H$_2$(g) → C$_6$H$_6$(g)

      a)   + 739 kJ
   b)   + 573 kJ
      c)   - 573 kJ
      d)   - 656 kJ

The following information refers to the next two questions.
Examine the following potential energy diagram for a chemical reaction:

Relative energy
kJ

60

40

20

0

reactants

products

Time
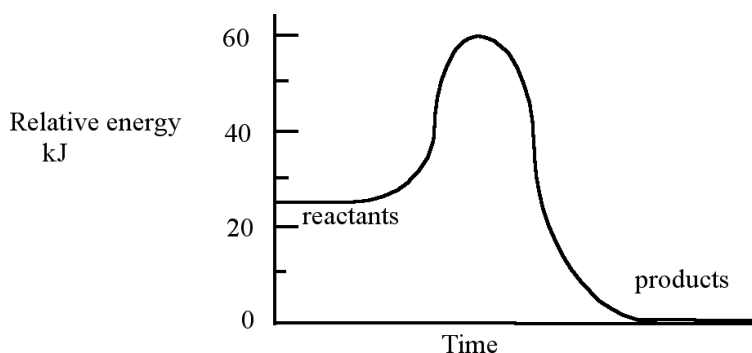
5.   The enthalpy change ΔH and the activation energy Ea in kJ for the reaction
      are respectively

      a)   ΔH = −25 kJ   and E$_a$ = 35 kJ
      b)   ΔH = +25 kJ   and E$_a$ = 35 kJ
      c)   ΔH = +35 kJ   and E$_a$ = 60 kJ
      d)   ΔH = −60 kJ   and E$_a$ = 35 kJ

6.   If a catalyst is added to the system (choose one answer):

      a)   both ΔH and E$_a$ decrease
      b)   ΔH remains constant but E$_a$ decreases
      c)   ΔH decreases and E$_a$ remains constant
      d)   both ΔH and E$_a$ remain constant.

7. The equilibrium constant, K, for the reaction, $2H_{2(g)} + O_{2(g)} \rightleftharpoons 2H_2O_{(g)}$, is equal to 2×10^{81} at 25°C. This value suggests that

a) this reaction favours the forward reaction slightly more than the reverse reaction.
b) this reaction favours the reverse reaction slightly more than the forward reaction.
c) this reaction virtually goes to completion with little reversal.
d) this reaction virtually does not proceed forward and largely favours the reactants.

8. The equilibrium expression, K, for the reaction below would be:

$$N_2O_{4(g)} \rightleftharpoons 2NO_{2(g)}$$
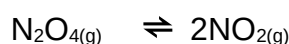
a) $K = \dfrac{[N_2O_4]}{2[NO_2]}$

b) $K = \dfrac{2[NO_2]}{[N_2O_4]}$

c) $K = \dfrac{[N_2O_4]}{[NO_2]^2}$

d) $K = \dfrac{[NO_2]^2}{[N_2O_4]}$

9. What would happen to the value of K in the reaction described in question 8, if the pressure of the N_2O_4 is doubled?

a) K would not be affected.
b) K would be halved.
c) K would be doubled.
d) K would increase by a factor of 4.

10. What is the equilibrium constant expression for the dissolving of solid silver sulfate in water?

(a) $K = \dfrac{[Ag^+]^2\,[SO_4^{2-}]}{[Ag_2SO_4]\,[H_2O]}$

$K = \dfrac{[Ag^+]\,[SO_4^{2-}]}{[H_2O]}$

(c) $K = \dfrac{[Ag^+]^2\,[SO_4^{2-}]}{[Ag_2SO_4]}$

(d) $K = [Ag^+]^2\,[SO_4^{2-}]$

SECTION 1 (MULTIPLE CHOICE) CONTINUED ON NEXT PAGE
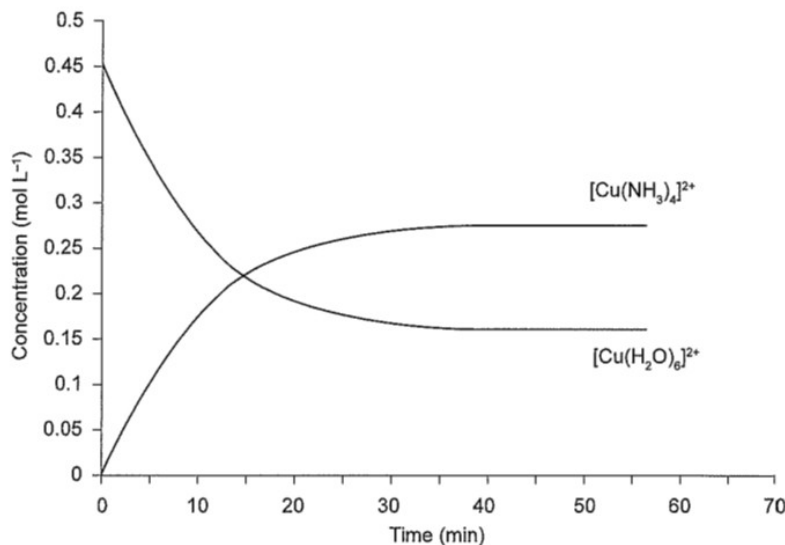
Questions 11 and 12 refer to the following diagram

Aqueous solutions of copper (II) ions and ammonia form the equilibrium presented below:

$$[Cu(H_2O)_6]^{2+}_{(aq)} + 4\ NH_{3\ (aq)} \rightleftharpoons [Cu(NH_3)_4]^{2+}_{(aq)} + 6\ H_2O_{(l)}$$
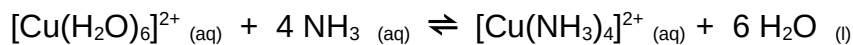
Pale blue   deep royal blue

The following graph shows the changes in concentration with time for $[Cu(H_2O)_6]^{2+}$ and $[Cu(NH_3)_4]^{2+}$ ions when solutions of copper (II) nitrate and ammonia are mixed.

11.   Which one of the following statements is true for this equilibrium system?

a)   The system reaches equilibrium at approximately 35 minutes.
b)   At equilibrium, the concentration of NH_3 will always be four times greater than the concentration of $[Cu(NH_3)_4]^{2+}$
c)   Adding ammonia to the system will decrease the equilibrium constant.
d)   At equilibrium, the rate of the forward reaction is less than the rate of the reverse reaction.

12.   Which one of the following would be observed if a small quantity of concentrated nitric acid was added to the system after it had reached equilibrium?

a)   The solution would be a deeper royal blue colour.
b)   The solution would be a paler blue colour.
c)   There would be no change in the colour of the system.
d)   Copper(II) nitrate crystals would precipitate from solution.

END OF SECTION 1

Section Two: Short answer   **(48 Marks)**

1. According to collision theory, what two criteria must be met before a molecular collision will result in a chemical reaction?

   Collision with sufficient energy (particles possess minimum energy to overcome Ea

   **Favourable orientation** (2)

2. State what is meant by the terms 'rate of reaction' and 'activation energy'.

   Rate of reaction **Change in <u>concentration</u> <u>per unit time</u> (1)**

   ....

   Activation energy **Minimum energy (1) necessary for a reaction to occur or for successful collisions (1)**

   (3)

3. The diagram below shows the energy distribution curve for a sample of gas at a fixed temperature. E_a is the activation energy for the decomposition of this gas.
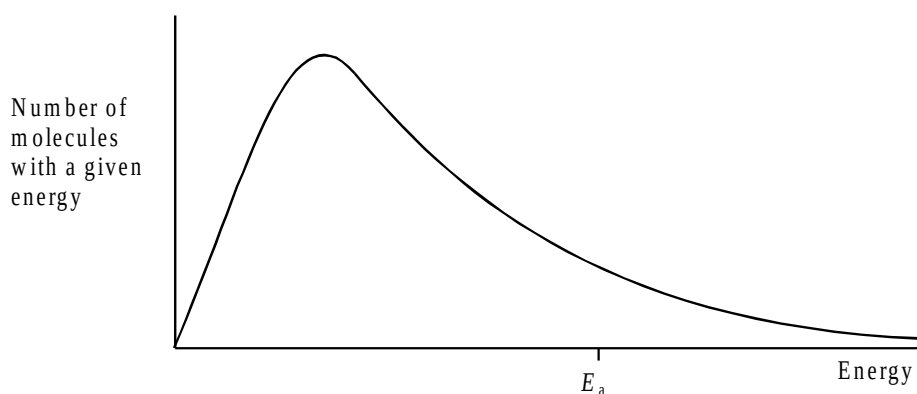
   a) On this diagram sketch the distribution curve for the same sample of gas at a higher temperature. (1)

   Peak lower and moved to right (1)

b) What is the effect of an increase in temperature on the rate of a chemical
reaction? Explain your answer with reference to the energy distribution curve on the previous page.

Effect.. **(Rate of reaction) <u>increases</u> (1)**..........

Explanation **(At a higher temperature) <u>more molecules/particles</u> (1) have the minimum energy needed to react/have activation energy/have successful collisions (1)**

....

c) What is the effect of the addition of a catalyst on the rate of a chemical
reaction? Explain your answer with reference to the energy distribution curve on the previous page.

Effect.. **(Rate of reaction) <u>increases</u> (1)**.

Explanation **Catalyst provides an alternative route (1)**

with a lower activation energy so that more molecules are able to react (1)

....

4. The questions below refer to the equilibrium of $Co(H_2O)_6^{2+}$ and $CoCl_4^{2-}$ ions in solution.

$$Co(H2O)62+ (aq) + 4 Cl- \rightleftharpoons (aq) \quad CoCl42- (aq) + 6 H2O (l) \qquad \Delta H$$
= positive
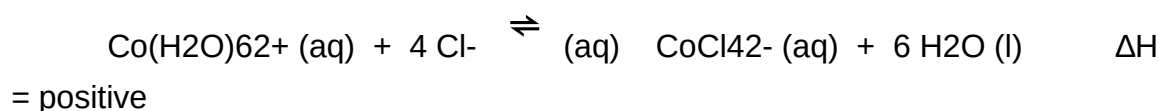
Pink   **blue**

a) Write the equilibrium constant expression for the following reaction. (1)

$$K = \frac{[CoCl_4^{2-}]}{[Co(H_2O)_6^{2+}]}$$
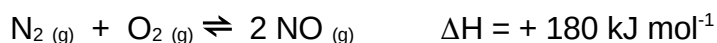
b) What would be observed if a few drops of silver nitrate solution (AgNO3 (aq)) were added? Explain this observation using Le Chatelier's principle. (3)

White ppt, solution would turn more pink   (1)

PPT of Cl- ions as AgCl   (1)

System shifting to the left to oppose change   (1)

5.   This question relates to the following reaction: (6)

$$N_{2 (g)} + O_{2 (g)} \rightleftharpoons 2\ NO_{(g)} \qquad \Delta H = +\ 180\ kJ\ mol^{-1}$$

Complete the table by predicting and **explaining** the effect on the position of equilibrium of the following imposed changes. **(simply stating Le Chateliers principle does not constitute an explanation)**

Imposed change	Affect on equilibrium position (to right, to left, or no change)	Explanation
Increased Temperature	**To right**	**Endothermic reaction, system will partially oppose by moving in endothermic direction, favouring products**
Reduce the volume of the reaction vessel	**No change**	**Same number of moles on both sides of equation**
Remove some of the NO$_{(g)}$	**To right**	**Decrease in product, system will partially oppose change, favour products**

6. During the production of nitric acid, the following exothermic reaction occurs:

$$4\ NH_{3\ (g)}\ +\ 5\ O_{2\ (g)} \rightleftharpoons\ 4\ NO_{\ (g)}\ +\ 6\ H_2O_{\ (g)}$$
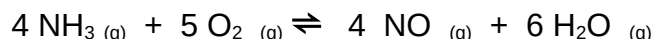
Chemical engineers would seek to try to increase both the rate and the yield for this process.

a) Give three actions, with brief explanations **using your knowledge of Collision theory**, that would maximise (increase) the **rate** of the forward reaction.   (3)

| Action	Explanation
Increase temperature	Collisions would have <u>higher energy</u> so more would have <u>greater than activation energy</u> for the reaction. (not just 'more successful collisions')
Increase pressure/ concentrations of gases	<u>More (successful) collisions</u> between molecules so greater reaction rate.
Use a catalyst	Catalyst <u>lowers the activation energy</u> so more collisions would have greater than activation energy.

b) Give two actions, with explanations **using your knowledge of Collision theory**, that would maximise the **yield** for the reaction.   (4)

Action	Explanation
Reduce temperature	The system will favour the forward reaction (<u>exothermic</u>) to compensate for the reduction in temperature
Reduce the pressure	The system will favour the forward reaction to compensate for the reduction in pressure as there are <u>more gaseous molecules</u> on the product side of the equation.
Increase the concentration of ammonia and/or oxygen	The system will oppose the change by favouring the forward reaction to <u>reduce the concentration</u> of these reactants.
Remove NO and/or H_2O as it is produced	The system will will oppose the change by favouring the forward reaction to <u>increase the concentration</u> of these products.

c) What would the chemical engineers have to do if an answer to (a) is an opposite action to an answer in (b)?   (2)

A <u>compromise</u> set of conditions will have to used

7. In our blood, oxygen is transported by combining with haemoglobin in the blood according to the following reversible reaction to form oxyhaemoglobin that travels around the body: (4)

$$HAEMAGLOBIN_{(aq)} + O_2_{(g)} \rightleftharpoons OXYHAEMAGLOBIN_{(aq)}$$
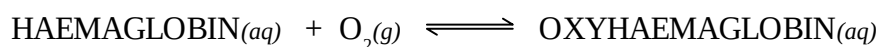
The presence of carbon monoxide in the blood causes the following irreversible reaction.

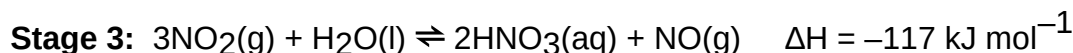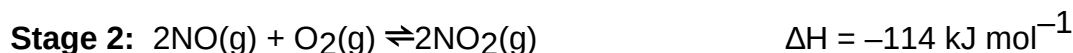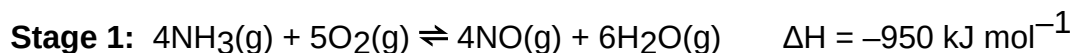$$HAEMAGLOBIN_{(aq)} + CO_{(g)} \longrightarrow CARBOXYHAEMAGLOBIN_{(aq)}$$
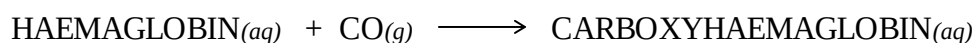
The concentration of oxygen in a person's blood is 0.01 mol L^{-1}. The blood in the person's body undergoes the following changes. Predict the effect of these changes on the oxygen concentration in the blood.

Imposed change	Concentration of oxygen	Explanation
Haemoglobin concentration in blood is increased.	**Less** than 0.01 mol L^{-1}	The system moves in the forward direction in order to oppose the increase in haemoglobin concentration.
$CO_{(g)}$ levels in blood increases.	**More** than 0.01 mol L^{-1}	The CO will remove haemoglobin and hence the reverse reaction will be favoured to counteract the reduction in haemoglobin concentration.

Explanation must talk about counteracting/opposing

8.   The industrial process for converting ammonia into nitric acid is done in three stages.

Stage 1: $4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g)$ $\Delta H = -950$ kJ mol^{-1}

Stage 2: $2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$ $\Delta H = -114$ kJ mol^{-1}

Stage 3: $3NO_2(g) + H_2O(l) \rightleftharpoons 2HNO_3(aq) + NO(g)$ $\Delta H = -117$ kJ mol^{-1}

Consider the reaction in **Stage 1** above.

a) State how the temperature should be changed in order to **increase the yield** at equilibrium in this reaction. Explain using Le Chatelier's principle.

Decrease the temperature/low temperature   (1)
The forward reaction is exothermic   (1)
a low T will favour the forward reaction/products
as the system is opposing the change to produce more heat
energy   (1)

b) State how the pressure should be changed in order **to increase the yield** at equilibrium in this reaction. Explain using Le Chatelier's principle.

Low pressure   (1)

9 molecules on reactant side, 10 on product side   (1)

A decrease in pressure will mean that the system will partially oppose

This change producing more particles, favouring the products (1)

c) The Stage 1 reaction is carried out by passing ammonia and air over a platinum gauze at a temperature of 900°C and a pressure of 975 to 1225 Pa. Using your knowledge of Collision Theory, what are the advantages of using this temperature and this pressure?

Both the temperature and pressure are fairly high.
A high temperature will mean the average kinetic energy of particles is higher **(1)**
Therefore, more particles will be able to overcome activation energy, resulting in more successful collisions. **(1)**
A higher pressure will mean that there are more particles per volume. **(1)**
Therefore more collisions, faster rate **(1)**

d) Give two reasons why the catalyst is used in the form of a gauze.

Increased surface area, more contact between reactant particles and

catalyst.

e) Catalysts are expensive. They greatly increase the cost of a chemical process, yet are still economically viable. Explain the role of catalysts and why they are used despite the cost.

Catalysts work by lowering the activation energy thereby increasing the amount of particles that are able to overcome Ea, therefore more successful collisions. **(1)**
Catalysts are not used up in the reaction **(1)**

END OF TEST