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| Description: Vertical full colour positive | Safety Bay Senior High School | | | | |
| **CHEMISTRY UNIT 3 & 4** | | | | | |
| **Practical #1:** | | | | | |
| **Changes to Systems at Equilibrium** | | | | | |
|  | | | | | |
| **NAME:** | | |  | | |
|  | | |  | | |
| **Time allowed for this practical** | | | | | |
| Reading time: | | 5 minutes | | | |
| Working time: | | 55 minutes | | | |
|  | | | | | |
| **Structure of this paper:** | | | | | |
| Number of questions | | | | Marks available | Marks achieved |
| 3 | | | | 45 | \_\_\_\_\_\_ / 45 |

**Instructions**

***Laptops***

Parts of this test will involve watching videos of experiments and making observations from these videos. There will be instructions in the test when this is necessary (e.g. "Watch video 2A"). The videos do not have any sound.

To access the videos you will need to log into a laptop. The three video files are on USB. Copy and paste the videos to the desktop, and then pass on the USB to someone else.

You are allowed to set up the laptop and watch the videos during the initial 5 minutes reading time.

***Heating of Co(H2O)62+ / CoCℓ42- mixture***

Questions 2d-2f require you to heat a solution that is at equilibrium. Perform all experiments at the lab benches. DO NOT bring the liquids back to your desk.

At the end of the lesson the mixture will be collected. Rinse the test tubes and return all equipment to its original location.

**Reaction System #1 (10 marks)**

Consider the following reaction: C(g) + Y(g) ⇌ 3B(g) + heat

C is a colourless gas, Y is a bright yellow gas, B is a bright blue gas. The system is initially at equilibrium and has a green colour (a mixture of yellow and blue).

The gas was separated into five containers and a change was applied to each container.

For each change:

* Describe the direction of shift in equilibrium after the change is imposed
* State how the colour of the gas mixture would change after the initial change and while the system re-establishes equilibrium. You may use terms like “more blue” or “more yellow” in your answer.

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| **Imposed change** | **Direction of shift**  **(‘left’, ‘right’, or ‘no change’)** | **Changes in gas colour** |
| Removing a large quantity of C without changing the volume of the container | **Left** | **More yellow** |
| Heating the system | **Left** | **More yellow** |
| Decreasing the volume in the system | **Left** | **Initially darker green,  then more yellow over time** |
| Adding another substance that reacts with Y to produce a yellow solid. | **Left** | **Initially more blue,**  **then returns to green over time** |
| Adding a catalyst | **No change** | **No change** |

**1 mark per box. Students should recognise difference between initial colour change and the change due to equilibrium shift for situation #3 and #4. Changes in gas colour must match direction of shift (e.g. if shift is 🡪 for first answer then colour change is more blue)**

**Reaction System #2 (20 marks)**

Co(H2O)62+ (aq) + 4 Cℓ- (aq) ⇌ CoCℓ42- (aq) + 6 H2O (ℓ)

pink blue

1. Write an equilibrium constant expression for this reaction. (1 mark)
2. Describe the effect of adding concentrated hydrochloric acid to this system. Explain the reasons for this effect in terms of collision theory. (4 marks)

* **Adding HCℓ increases rate of forwards reaction due to more collisions between reactant particles. This causes more CoCl42- to be produced and more Co(H2O)62+ to be consumed, resulting in the solution turning blue.**

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| **Answer criteria** | **Marks** |
| Recognises increase in forwards reaction rate | 1 |
| Explains increase in forwards reaction rate using collision theory | 1 |
| Uses rates to explain changing concentrations of CoCl42- and Co(H2O)62+ | 1 |
| Links changing concentrations to observations (solution turns blue) | 1 |

1. Sketch a graph which shows the effect of adding concentrated HCℓ to this system. (5 marks)

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HCℓ added

Concentration

Time

Co(H2O)62+

Cℓ-

CoCℓ42-

|

Equilibrium established

|  |  |
| --- | --- |
| **Answer criteria** | **Marks** |
| Initial increase in Cℓ- | 1 |
| *Partial* decrease in Cℓ- over time | 1 |
| CoCl42- increases and Co(H2O)62+ decrease over time, slopes are correct shape | 1 |
| Ratios of reacting species correct   * Co(H2O)62+ decreases ¼ as quickly as Cℓ- decreases * CoCl42- increases ¼ as quickly as Cℓ- decreases | 1 |
| Constant concentrations after equilibrium is re-established | 1 |

You have been provided with samples of a mixture of Co(H2O)62+ and CoCℓ42-. The colour of the solution is due to a mixture of the pink and blue species in the reaction.

Co(H2O)62+ (aq) + 4 Cℓ- (aq) ⇌ CoCℓ42- (aq) + 6 H2O (ℓ)

pink blue

1. Is the forwards reaction endothermic or exothermic? Justify your answer using your observations and by applying Le Chatelier’s principle. (3 marks)

* **When the mixture is heated it turns more blue. According to Le Chatelier’s principle, heating a system will favour the endothermic reaction. Therefore the forward reaction is endothermic.**

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| **Answer criteria** | **Marks** |
| Provides observation | 1 |
| Uses L.C.P. to predict that endothermic reaction is favoured by heating | 1 |
| Combines observation and L.C.P. to conclude that forwards reaction is endothermic | 1 |

1. Describe the effect of heating the solution on the initial rate of the forwards and reverse reactions. (2 marks)

* **Both the forward and reverse reaction rates increase, but the forward rate increases more than the reverse rate.**

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| --- | --- |
| **Answer criteria** | **Marks** |
| Recognises that **both** rates increase | 1 |
| Recognises the forward rate increases relative to reverse rate | 1 |

1. Draw an energy profile diagram for the reversible reaction between [Co(H2O)6]2+ and [CoCℓ4]2-, showing the reactants, products, Ea and ∆H. Include appropriate labels of each axis. (5 marks)

**ΔH**

**Ea**

**reactants**

**products**

**reaction progress / reaction coordinate / time**

**enthalpy / potential energy**

|  |  |
| --- | --- |
| **Answer criteria** | **Marks** |
| Axes labels | 1 |
| Endothermic graph shape *(allow follow-through if 2(d) said ‘exothermic’)* | 1 |
| ‘Reactants’ and ‘Products’ labelled (either with words or the formulas of the species) | 1 |
| Ea shown correctly and labelled | 1 |
| ΔH shown correctly and labelled | 1 |

**Reaction System #3 (15 marks)**

Nitrogen dioxide (a brown gas) exists in dynamic chemical equilibrium with dinitrogen tetroxide (a colourless gas).

1. Write a chemical equation to represent the reaction between these two substances.

(2 marks)

2 NO2(g) ⇌ N2O4(g)

|  |  |
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| **Answer criteria** | **Marks** |
| Balanced equation | 1 |
| Reversible arrows used | 1 |

1. Write an equilibrium expression which matches the equation given in part (a).

(1 mark)

**Watch Video 3A & 3B: Effect of Pressure**

**Both videos show the same change for the same reaction but have different lighting   
conditions and quality. Watch both to ensure you have made the correct observations.**

1. Describe the visible changes that occur when the syringe is quickly pulled outwards, increasing the volume in the syringe. (2 marks)

* **Initially the mixture fades but then the dark brown colour returns.**

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| **Answer criteria** | **Marks** |
| Initial change: lighter brown / fades | 1 |
| Over time: becomes darker brown | 1 |

1. Account for the colour changes you described in part (c). (3 marks)

* **The mixture fades initially because the volume has increased and this means the brown NO2 is less concentrated.**
* **Increasing the volume means that the system is not at equilibrium. It will favour the side of the reaction with the most moles of gas, leading to the production of more NO2. This results in an increasing brown colour over time.**

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| **Answer criteria** | **Marks** |
| Initial fade caused by gases being less concentrated | 1 |
| Darker brown over time is caused by reaction shifting to the left, producing more NO2 | 1 |
| Explains, in terms of moles of gas, *why* reaction shifts to the left | 1 |

1. Sketch a rough graph which shows the effect of increasing the volume of the syringe on both the forwards and reverse reaction rates for this reaction. Assume the system is initially at equilibrium.

*Note: Your definitions of “forwards” and “reverse” should match the equation you gave in part (a).* (5 marks)

Reaction rate

Time

|

Volume is increased

|

Equilibrium re-established

**Reverse rate (N2O4 🡪 2 NO2)**

**Forward rate (2 NO2 🡪 N2O4)**

|  |  |
| --- | --- |
| **Answer criteria** | **Marks** |
| Reaction rates are initially equal | 1 |
| Decrease causes an initial drop in the rate of forwards reaction | 1 |
| Decrease causes a smaller initial drop in the rate of reverse reaction | 1 |
| Two rates equalise over time, correct graph shape | 1 |
| Reactions rates equal again when equilibrium re-established | 1 |

1. Decreasing the volume of a container is one way of increasing the pressure of a system. Another method of increasing pressure is to introduce more moles of gas without changing the volume of the container.

Predict how the addition of carbon dioxide would affect this system, assuming that it is initially at equilibrium. Provide a reason for your prediction. (2 marks)

* **Addition of CO2 would have no effect as CO2 is an inert gas.**

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| **Answer criteria** | **Marks** |
| Predicts no effect | 1 |
| Recognises CO2 is an inert gas | 1 |

**END OF TEST**

**SPARE GRAPHS**

**Question 2c)**

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HCℓ added

Concentration

Time

Co(H2O)62+

Cℓ-

CoCℓ42-

|

Equilibrium established

**Question 2f)**

**Question 3e)**

Reaction rate

Time

|

Volume is increased

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Equilibrium re-established