Equilibrium

In the laboratory, Julie and Chris observe and then describe several experiments. Which of their descriptions corresponds to a system at equilibrium?

A) The flame of a candle that is standing on the counter-top has a constant form. The size and colour of the flame remain the same for one hour.

B) Water in a beaker is heated to the boiling point. The temperature remains at 100°C while the water is boiling.

C) In a stoppered test-tube, at a constant temperature, the amount of reactants (mercury and oxygen) remains constant and the amount of products (mercuric oxide) remains constant.

D) In a sealed container, a piece of zinc gets smaller as it reacts with hydrochloric acid. Gas bubbles are formed and the temperature increases.

3 The industrial production of sulphuric acid is simple. There are three steps:

1 The sulphur is extracted from the ground and burnt to produce SO_2.

2 The SO_2 is then oxidized to produce SO_3.

3 The SO_3 reacts with water to give H_2SO_4.

The second stage is shown in the equation below:

$$2\,SO_{2(g)} + O_{2(g)} \leftrightarrow 2\,SO_{3(g)} + 192.4\ kJ$$

Complete the following statement:

If the pressure of the system is increased, the equilibrium will move to the _____ and the concentration of SO_3 will _____

4 Fritz Haber, a German scientist, developed a procedure for producing ammonia according to the equation below:

$$N_{2(g)} + 3\,H_{2(g)} \leftrightarrow 2\,NH_{3(g)} + 95.4\ kJ$$

State three different factors that will favour the production of ammonia.

4n gas ⇆ 2n gas

6 We are presented with the following system at equilibrium :

$$N_{2(g)} + 3\ H_{2(g)} \leftrightarrow 2\ NH_{3(g)} + 102\ kJ$$

What changes, among the following, will favour a forward reaction? **Explain why!!!!**

1. An increase in the NH_3 concentration →
2. A decrease in temperature
3. An increase in pressure brought on by a decrease in volume
4. Adding a catalyst

A) 1 and 2 C) 2 and 3

B) 1 and 4 D) 3 and 4

8 Hydrogen gas, Oxygen gas, and liquid water are at equilibrium in a closed system as indicated in the following equation.

$$H_{2(g)} + 1/2\ O_{2(g)} \leftrightarrow H_2O_{(g)} + \text{Heat}$$

Predict and **explain** the effect each of the following changes will have on the system at equilibrium.

Show all work!

1. An increase in temperature ↑T ⇒ ↓T = ←
2. An increase in pressure ↑P ⇒ ↓P = →
3. An increase in the $H_{2(g)}$ concentration →

9 Among the following situations, which one represents a state of equilibrium?

A) The growth of algae at the bottom of a lake X not closed

B) Wine in a sealed bottle yes (vapour ⇆)

C) An inflated tire no ⇆

D) The digestion of food not closed / not constant

system reaches equilibrium according to the following equation :

$$4\,Fe_{(s)} + 3\,O_{2(g)} \leftrightarrow 2\,Fe_2O_{3(s)} + 1\,660\ kJ$$

Which of the following modifications favor the formation of $Fe_2O_{3(s)}$? want to shift to the right

1. An increase in temperature
2. A decrease in temperature → shift
3. An increase in pressure → to ↓ # n of gas
4. A decrease in pressure
5. An addition of a catalyst
6. An increase in the quantity of oxygen → shift
7. A decrease in the quantity of oxygen

2, 3 & 6

11 Observing a beaker containing a saturated iodine solution at equilibrium, a student notices that the solution maintains a constant coloration.

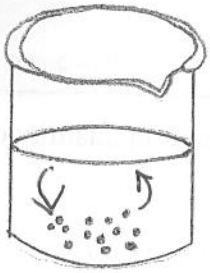
Knowing that iodine continues to be dissolved, briefly **explain** why the coloration no longer varies. **Draw on the diagram, as well!!!!!**

solid ⇋ soln

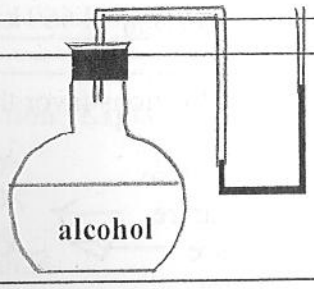
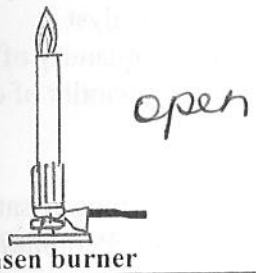
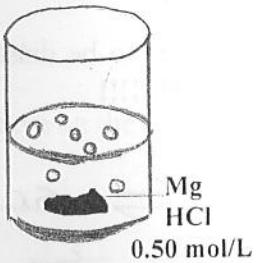
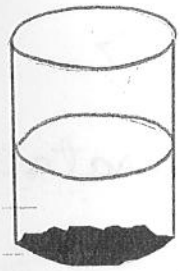
dissolves ⇋ crystallizes out

the rate of the dissolving = the rate of crystallizing out

sat. soln = sup at ⇋



12 Here are four illustrations representing chemical systems.

1)	~~Constant quantity of liquid alcohol~~ Constant pressure Constant temperature ⇌	
2)	Constant height of flame Constant temperature escaping	
3)	Constant quantity of liquid Constant evolution of gas open escaping	
4)	Constant quantity of $NaCl_{(s)}$ Constant quantity of salt solution Constant mass of water-salt system	sat sol'n ⇌ 

Which illustrations represent open systems? **And why in each case???**

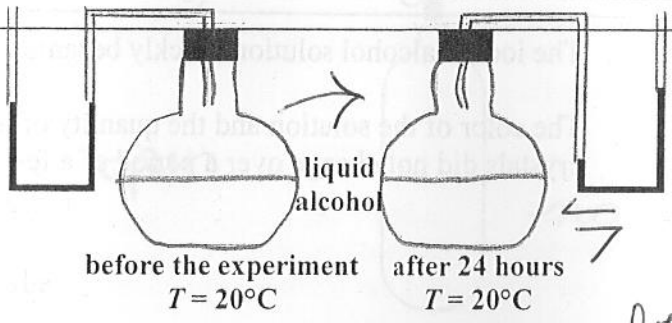
A) Illustrations 1 and 4

B) Illustrations 2 and 3

C) Illustrations 2 and 4

D) Illustrations 3 and 4

You introduce alcohol into a flask fitted with a manometer, as illustrated below. After 24 hours, you observe that the **macroscopic** properties of the system are constant.



= at ⇌ both processes to continue to take place

Here are five explanations of the situation:

1. The evaporation of the alcohol has stopped because the volume of the liquid has remained constant.

2. The temperature remains constant; there is no more reaction. rxn continues but can't see it

3. The rate of evaporation is the same as the rate of condensation.

4. The condensation of alcohol vapour has stopped because the pressure has remained constant and the volume of liquid is constant.

5. All molecular activity has stopped because the macroscopic properties are constant.

Which explanations could explain the constant properties?

A) 1, 2 and 4
B) 3 and 5
C) 3 alone
D) 5 alone

= closed

14 In a combustion chamber, ethane, $C_2H_{6(g)}$ is burnt in pure oxygen. After several minutes the system reaches equilibrium at high temperature.

The equation of the reaction is:

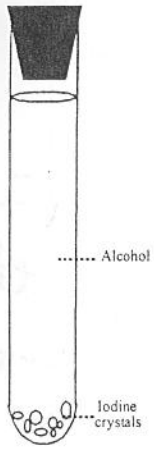
4.5 n gas 5 n gas

$C_2H_{6(g)} + 7/2\ O_{2(g)} \leftrightarrow 2\ CO_{2(g)} + 3\ H_2O_{(g)} + \text{energy}$

What could be done to favour the formation of $CO_{2(g)}$? → to the right

A) Raise the temperature and lower the pressure. ← →
B) Lower the pressure and cool the system. → →
C) Add a positive catalyst. no effect = sys gets to eq ⇌ position faster but same position
D) Add oxygen gas and increase the pressure. → ←

15 In order to study the conditions in a system at equilibrium, some iodine crystals were placed in alcohol, as in the diagram below.



The iodine-alcohol solution quickly became reddish-colored.

The color of the solution and the quantity of non-dissolved iodine crystals did not change over a period of a few days.

rates

Which analogy might best explain the **dynamics**, at the **microscopic** level, of this equilibrium system?

A) A ~~dam~~ where the water level is constant. The amount of water leaving the dam is exactly the same as the water approaching the dam.

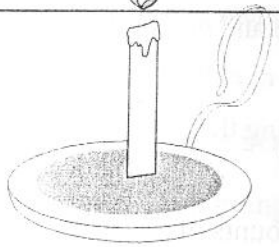
B) A hockey game in which six players are on the ice at the same time. As one player leaves the bench to join the play, another player goes to the bench.

C) A line-up at the cash in the cafeteria. As soon as a student pays, the length of the line-up decreases. steady state

D) A full dance club on a Saturday night. As soon as one customer leaves the club, the doorman lets in a new customer. steady state

Which of the following represents a system at equilibrium?

A)



Burning candle

open

C)

Scuba diver's air tank

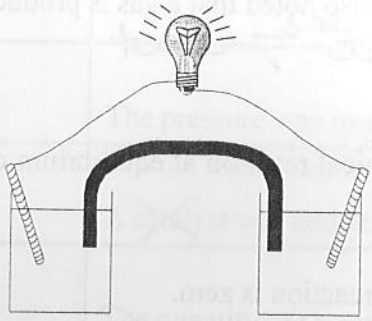
no ⇌ } must have 2 processes going on = for ⇌ rev

B)

Unopened soft drink bottle

⇌

D)



Electrochemical cell ⇌

<= you don't know about this yet

17 Which of the factors listed below would positively affect the production of carbon dioxide (CO_2) in the equilibrium system?

2 n gas → 2 n gas

$$CO_{(g)} + NO_{2(g)} \leftrightarrow CO_{2(g)} + NO_{(g)} + 227\ kJ$$

1. Increase the pressure on the system. no effect ← ↑HE
2. Increase the temperature.
3. Decrease the temperature. →
4. Add carbon monoxide (CO). →
5. Add a catalyst.

A) 1, 2 and 4

B) 1, 3 and 5

C) 2 and 5

D) 3 and 4

18 Julie and Chris observe and describe the behaviour of matter during various experiments in the lab. Which of the following descriptions matches a system at equilibrium?

A) The flame of a candle burning on the counter keeps its shape, size and colour during its hour-long combustion. open

B) The temperature of water in a beaker stays constant at 100°C during the entire time it boils. open

C) In a well-stoppered test tube kept at constant temperature, the amounts of reactants (mercury and oxygen) do not change and the amount of product (mercury oxide) does not change. ⇋

D) In a well-stoppered flask, the size of a piece of zinc decreases as it reacts with hydrochloric acid. It is also noted that a gas is produced and the temperature in the flask increases. not ⇋ yet

19 At the microscopic level, a chemical reaction at equilibrium can be explained by one of the following statements. Which one?

A) The rate of the forward reaction is zero.

B) The rate of the reverse reaction is zero.

C) The rate of the forward and reverse reactions are zero.

D) The rate of the forward reaction is equal to the rate of the reverse reaction.

20 Given the following reaction at equilibrium.

3 n gas → 2 n gas.

$$N_{2(g)} + 2\ O_{2(g)} + 67{,}8\ kJ \leftrightarrow 2\ NO_{2(g)}$$

Which of the following changes would favour the production of $NO_{2(g)}$?

A) ~~Reduce~~ the concentration of $N_{2(g)}$. ←

B) Reduce the temperature in the reaction chamber. ✗ ←

→ C) Reduce the volume of the reaction chamber. = ↑P = shift to side w fewer n gas to ↓P

D) Reduce the pressure in the reaction chamber. ←

In which one of the following situations can equilibrium be achieved?

A) ~~A mercury thermometer indicating room temperature~~

B) A hydroelectric dam in which the water level is constant open = steady state

C) An iron tool rusting in air open

D) A slice of bread burning in a toaster open

22 The following table shows four systems at equilibrium and the change made to each system.

	System at equilibrium	Change made
1.	$A_{(g)} + 2B_{(g)} \leftrightarrow C_{(g)}$	The pressure was increased. →
2.	$3D_{(g)} + 2E_{(g)} \leftrightarrow 2F_{(g)}$	A ~~catalyst~~ was added. ∅
3.	$2E_{(g)} + G_{(g)} \leftrightarrow E_2G_{(g)}$	The quantity of $G_{(g)}$ was reduced. ←
4.	$A_{(g)} + C_{(g)} \leftrightarrow 3D_{(g)}$	The volume was increased. = ↓P = →

In which system does the change favour the reverse reaction only? ←

A) 1

B) 2

C) 3

D) 4

23 The following orange-yellow solution is a system at equilibrium : our lab.

$$Cr_2O_7^{2-}{}_{(aq)} + 2OH^-{}_{(aq)} \leftrightarrow 2CrO_4^{2-}{}_{(aq)} + H_2O_{(l)}$$

orange + H^+ yellow

An acidic solution containing $H^+{}_{(aq)}$ ions is added to this system. = ↓[OH⁻] = real stress = shift left = more orange

What will happen to this orange-yellow solution after equilibrium is re-established?

A) It will become more orange.

B) It will become colourless.

C) It will become more yellow.

D) It will not change colour.

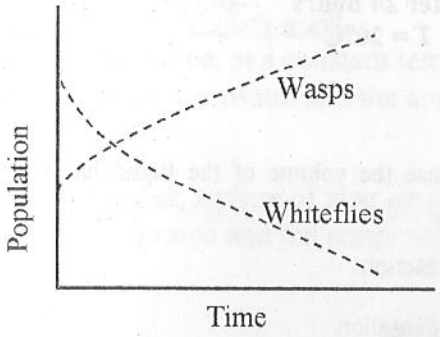
Equilibrium Questions

Operators of greenhouses must contend with a great variety of insect pests. Biological controls are available, which avoid the environmental contamination resulting from toxic chemicals. The Whitefly is a greenhouse pest that can be controlled by introducing the wasp, "Encarsia formosa".

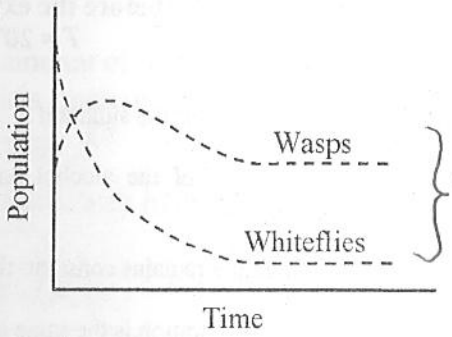
The graphs below show the results of four tests done in greenhouses with typical Whitefly infestations.

In which of these tests have the investigators succeeded in establishing equilibrium between the Whitefly and the wasp populations?

A)

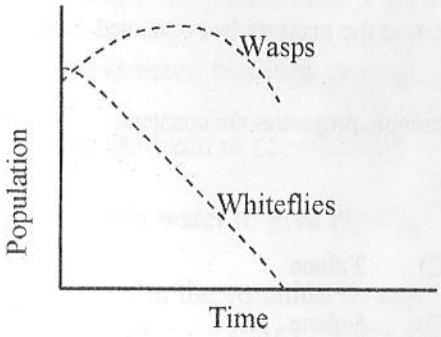


C)

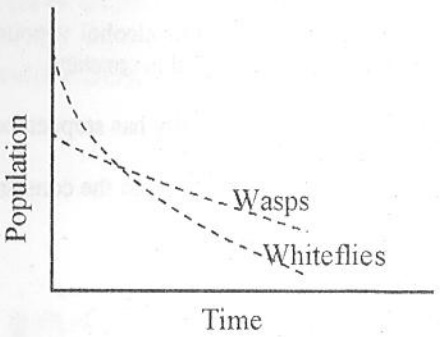


rate for = rate rev

B)



D)



$$2\,SO_{2(g)} + O_{2(g)} \leftrightarrow 2\,SO_{3(g)} + 192.4\ kJ$$

Complete the following statement:

stress = ↑P (↓V) sys wants ↓P = → to go from 3 gas to 2 gas

If the pressure of the system is increased, the equilibrium will move to the right and the concentration of SO_3 will increase

4 Fritz Haber, a German scientist, developed a procedure for producing ammonia according to the equation below:

$$N_{2(g)} + 3\,H_{2(g)} \leftrightarrow 2\,NH_{3(g)} + 95.4\ kJ$$

State three different factors that will favour the production of ammonia.

- ↑[N_2] or ↑[H_2]
- ↑P
- ↓T