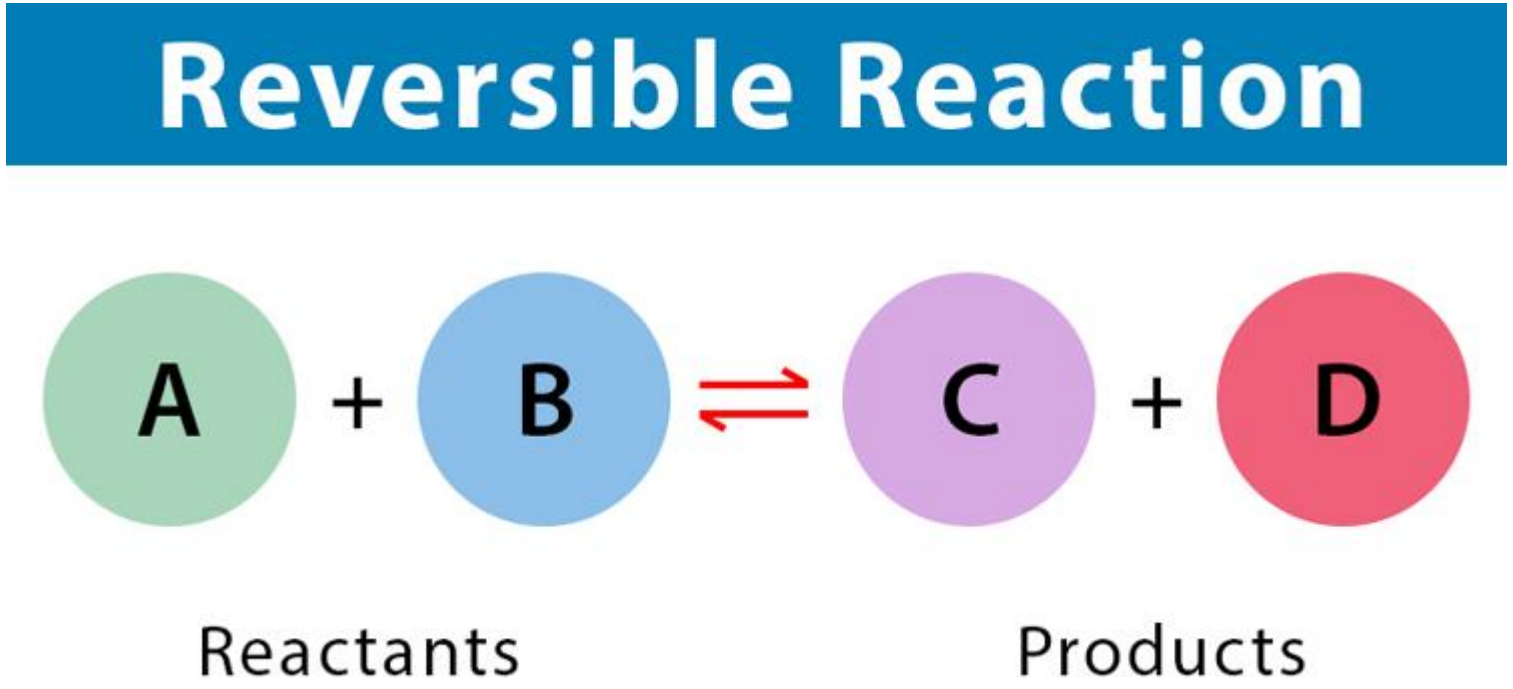
Reversible reactions



Reversible reactions

- In some chemical reactions, the products of the reaction can react together to produce the original reactants. These reactions are called reversible reactions. They can be represented in the following way:

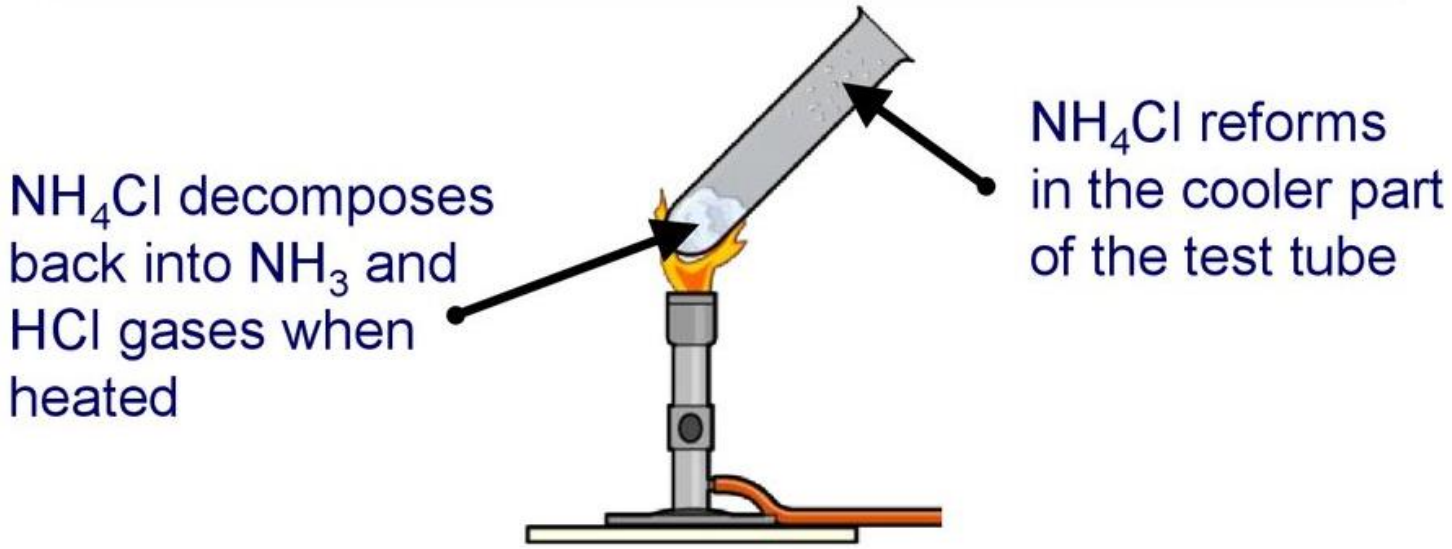
- $A + B \rightleftharpoons C + D$

- The symbol $\rightleftharpoons$ has two half arrowheads, one pointing in each direction. It is used in equations that show reversible reactions:

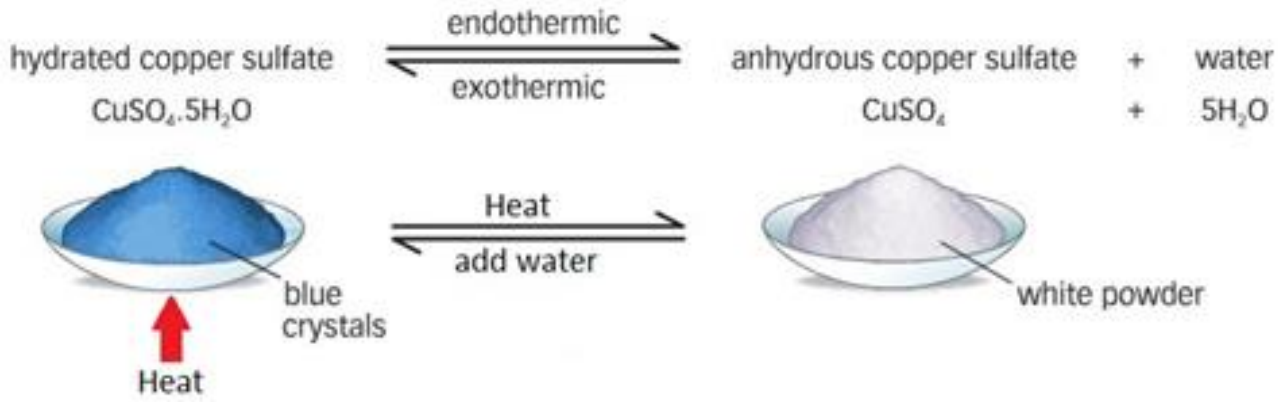
- the forward reaction is the one that goes to the right
- the backward reaction is the one that goes to the left
- The reaction mixture may contain reactants and products, and their proportions may be changed by altering the reaction conditions.

Ammonium Chloride

- Ammonium chloride is a white solid. It breaks down when heated, forming ammonia and hydrogen chloride. When these two gases are cool enough, they react together to form ammonium chloride again.
- ammonium chloride ⇌ ammonia + hydrogen chloride
- $NH_4Cl(s) \rightleftharpoons NH_3(g) + HCl(g)$



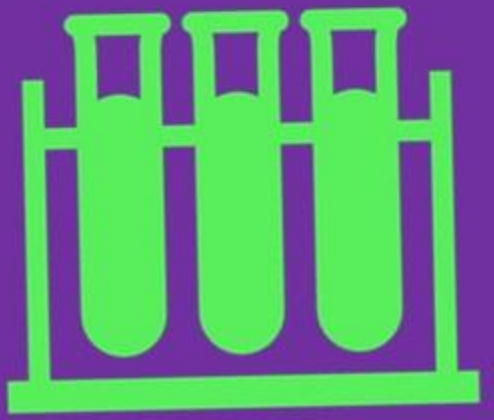
Energy Changes



If a reaction is exothermic in one direction, it will be endothermic in the other direction. The same amount of energy is transferred in both the forwards and reverse reaction.

What does exothermic and endothermic mean?

How can you tell if a reaction is endothermic?



Hydrated copper sulfate, $CuSO_4.5H_2O$, is a blue solid.
Anhydrous copper sulfate, $CuSO_4$, is a white solid.

Heat energy is needed to convert hydrated copper sulfate to anhydrous copper sulfate.
This is a reversible reaction.

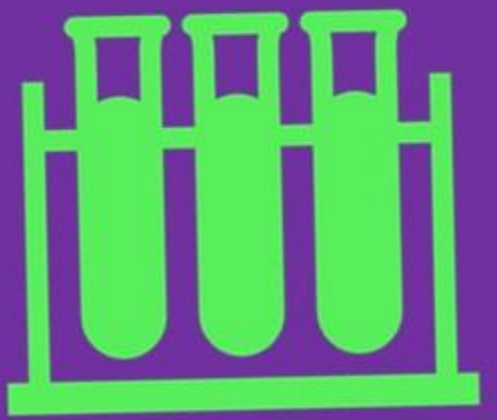
$$CuSO_4.5H_2O \rightleftharpoons CuSO_4 + 5H_2O$$

Devise an experiment to show that this is a reversible reaction.

(4)

.....

.....



Dynamic equilibrium

When a reversible reaction happens in a closed container, it reaches a dynamic equilibrium.

At equilibrium:

- the forward and backward reactions are still happening
- the forward and backward reactions have the **same rate of reaction**
- the concentrations of all the reacting substances remain constant

Changing the position of the equilibrium

- Temperature
- Pressure
- Concentration

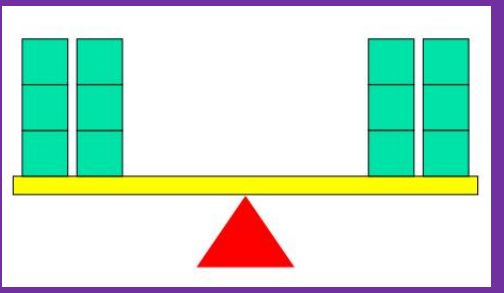


Figure 5 shows molecules of nitrogen, hydrogen and ammonia before the reaction and at equilibrium.

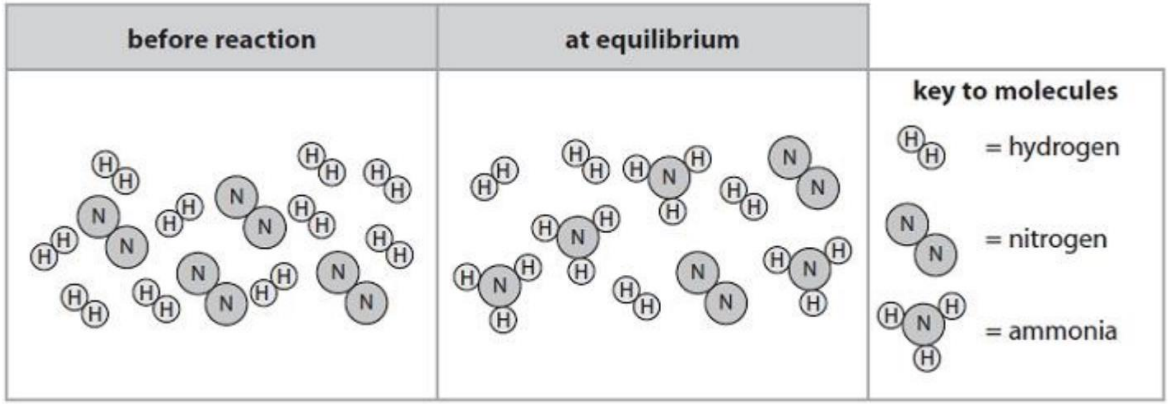


Figure 5

(i) Complete the table showing

- the number of hydrogen molecules before reaction
- the number of hydrogen molecules at equilibrium
- the change in the number of hydrogen molecules.

(1)

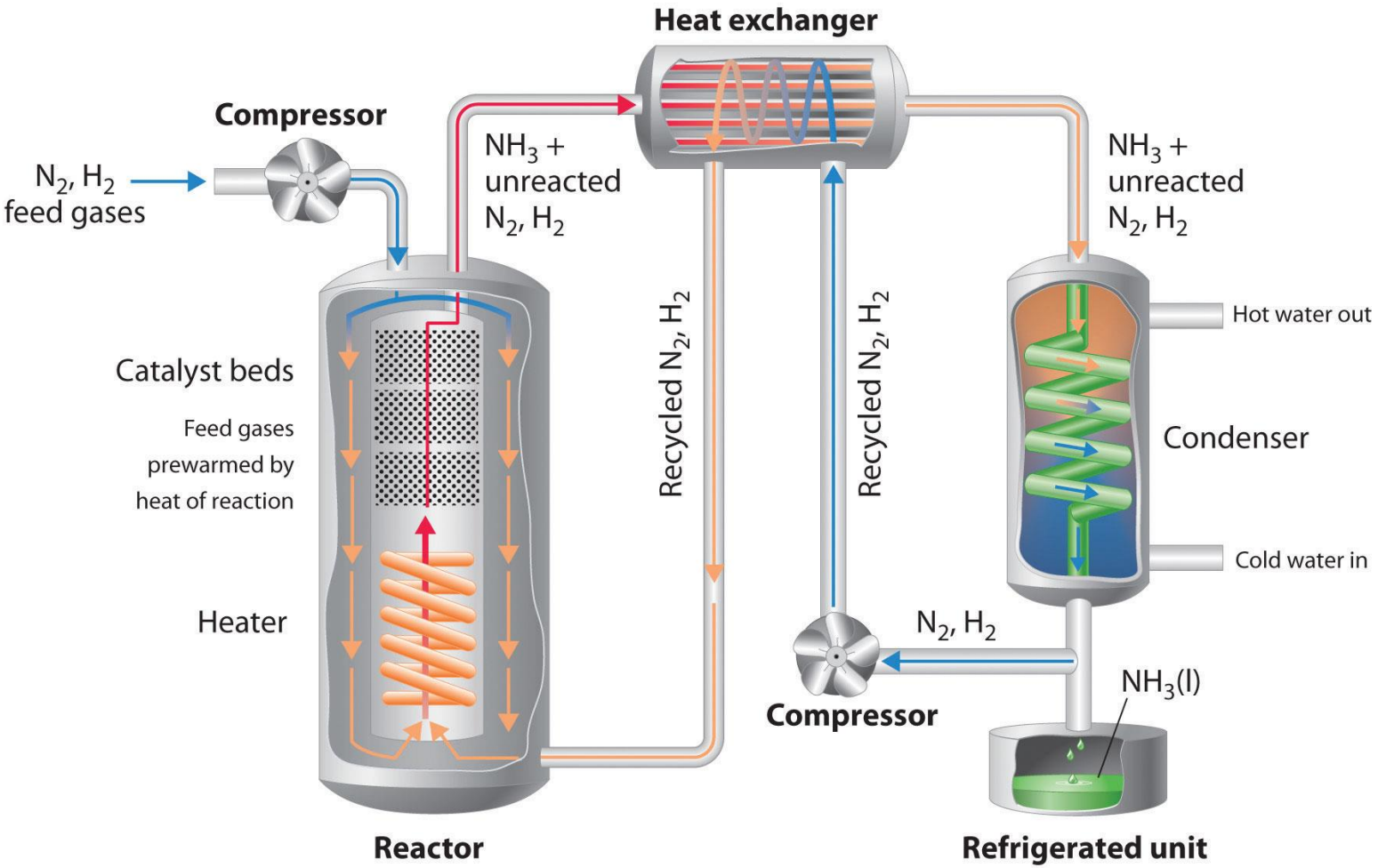
	number of molecules before reaction	number of molecules at equilibrium	change in number of molecules
nitrogen	4	2	–2
hydrogen	.....	.....	.....
ammonia	0	4	+4

(ii) Complete the equation for this reaction.

(2)

..... + ... ↔ 2 NH_3

The Haber Process



The Haber Process

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

There are more molecules on the left than on the right.

The forward reaction is exothermic, giving out energy.
The backward reaction is endothermic, taking in energy.

At equilibrium, the concentrations are constant.

If the pressure is increased in a reaction involving gases, the equilibrium position moves in the direction of the fewest molecules of gas, to reduce the pressure.

In a reversible reaction, if the reaction is exothermic in one direction, it is endothermic in the other direction. If the temperature is increased, the equilibrium position moves in the direction of the endothermic process.

If the concentration of a reactant is increased, the equilibrium position moves in the direction away from this reactant, and so more of the products are produced. If one of the products is removed from a reaction, then the position of equilibrium moves to the right to make more of that product.

Sulfur dioxide reacts with oxygen to make sulfur trioxide in a reversible reaction:
$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

Predict the effect of increasing the pressure.

The Haber Process Conditions

- Iron catalyst
- Pressure at 200atm
- Temperature at 450°C

Oxygen reacts with sulfur dioxide.

The reaction is reversible.

(d) What is the symbol for a reversible reaction?

_____

(e) Complete the sentence.

In a reversible reaction the forward reaction is exothermic, so the

reverse reaction is _____ .

(f) A reversible reaction happens in apparatus which stops the escape of reactants and products.

Complete the sentence.

Equilibrium is reached when the forward and reverse reactions happen at

exactly the same _____ .

When chloride ions are added to a pale blue solution containing copper ions, the mixture turns yellow.

This is a reversible reaction.

pale blue solution + chloride ions ↔ yellow solution + water

What effect does the removal of chloride ions have on the colour of the yellow mixture?

- ☐ **A** does not change colour
- ☐ **B** turns blue
- ☐ **C** turns colourless
- ☐ **D** turns darker yellow

The industrial production of sulfuric acid involves several steps.

One of these steps is the reaction of sulfur dioxide, SO_2, with oxygen to form sulfur trioxide, SO_3.

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

* The reaction to produce sulfur trioxide reaches an equilibrium.

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

The forward reaction is exothermic.
The rate of attainment of equilibrium and the equilibrium yield of sulfur trioxide are affected by pressure and temperature.

A manufacturer considered two sets of conditions, A and B, for this reaction.
In each case sulfur dioxide is mixed with excess oxygen.
The manufacturer changed the temperature and the pressure and only used a catalyst in B.
The sets of conditions A and B are shown in Figure 7.

set of conditions	pressure in atm	temperature in °C	catalyst
A	2	680	no catalyst used
B	4	425	catalyst used

Figure 7

The manufacturer chooses set of conditions B rather than set of conditions A.

Explain, by considering the effect of changing the conditions on the rate of attainment of equilibrium and on the equilibrium yield of sulfur trioxide, why the manufacturer chooses the set of conditions B rather than the set of conditions A.

(Total for question = 6 marks)