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Basic (Level 1 - 2 Learners)

- 1 (C) Pressure has no effect as there are 2 moles on both sides
- 2 (C)
- 3 (B)
- 4 (C) Concentrated H_2SO_4 dehydrates the solution to precipitate solid NaCl
- 5 (B) Both sides of the equation have an equal number of molecules and thus pressure has no effect. Increasing the volume of the chamber lowers the pressure.
- 6 (B) A catalyst only changes the rate.
- 7 (A) Cool exothermic reactions (+ 271 kJ)
- 8 (A)
- 9 (D)
- 10 (A) There are fewer gaseous products.
- 11 (B) Both have the ethanoate (acetic) ion.
- 12 (A) The product has fewer gaseous molecules
- 13 (B)
- 14 (C) There are two molecules on both sides, so pressure has no effect.
- 15 (C) Only the product has a gas. This is favoured as more gas is produced to fill the expanding container.

Difficult (Level 5 - 7 Learners)

- 1 (D) At equilibrium, graphs must be horizontal. Products must increase and reactants must decrease.
- 2 (A) At equilibrium, graphs must be horizontal. Rate of forward reaction must equal rate of reverse reaction.
- 3 (D) Reactants drop down to zero when they are used up.
- 4 (i) (A) A catalyst does not change the equilibrium
(ii) (A)
(iii) (A)
- 5 (B) Both graphs must be horizontal at equilibrium.
- 6 (i) (A) Reverse reaction is favoured to get rid of the excess product.
(ii) (D) Products get less, so reverse reaction is favoured. This is an endothermic reaction ($\Delta H > 0$) which produces cold, so we must cool it.
(iii) (A) The product chlorine is suddenly increased.
(iv) (B) The amount of PCl_3 suddenly drops.
- 7 (i) (A) The amount of H_2 suddenly increases.
(ii) (D) Product HF increases, favouring the forward exothermic reaction ($\Delta H < 0$) which produces heat.
- 8 (i) (A) HF suddenly increases.
(ii) (D) Product HF increases in an exothermic reaction that produces heat. Thus the reaction was cooled.
(iii) (B) HF suddenly drops as it was removed.
(iv) (C) A catalyst has no effect on the equilibrium.
- 9 (i) (C) More product is formed in an exothermic reaction that produces heat. Thus it was cooled.
(ii) (D) All the concentrations increased. Only a pressure increase can do this.
- 10 (i) (A) Product (NH_3) graph suddenly increases.
(ii) (D) Forward and reverse reaction rate increases, so concentration of reactants and products both increases. (Rate depends on concentration)
Only a pressure increase will increase all the concentrations.
(iii) (B) Product graph (dotted line) suddenly drops.
(iv) (C) A catalyst increases both rates, but because the equilibrium stays the same, there is no increase or decrease in the reactants and products (i.e. the graphs do not curve after the disturbance)
- 11 (i) (C) Both forward and reverse rates drop. Rates always drop with a decrease in temperature.
(ii) (D) All the concentrations dropped. Thus the pressure must have dropped, favouring the reverse reaction.
- 12 (i) (A) Reactants increase, so the reverse reaction is favoured.
(ii) (B) Products increase (dotted line rises) so we favoured the reverse reaction.
(iii) (C) Both forward and reverse rates dropped, so we cooled the reaction. Then more product formed, so the forward reaction to make product was exothermic.
(iv) (D) Both forward and reverse rates increased, so we heated the reaction. Then more product formed, so the forward reaction to make product was endothermic.
- 13 (i) (A) Both forward and reverse rates dropped, so we cooled the reaction. Then more reactants formed (dark line rises), so the reverse reaction to make reactants was exothermic. So the forward reaction to make products was endothermic.
(ii) (B) Both forward and reverse rates increased, so we heated the reaction. Then more reactants formed (dark line rises), so the reverse reaction to make reactants was endothermic. So the forward reaction to make products was exothermic.
- 14 (A) Exothermic reaction ($\Delta H < 0$) that produces heat must be cooled. Product has fewer gas molecules which favours higher pressures.
- 15 (D) Two molecules on both sides of equation means pressure has no effect. Catalysts do not affect yield. Because of large gaps between their molecules, each gas occupies the container as if it alone were in there. Noble gases do not react with anything.

Multiple Choice Questions

Difficult (Level 5 - 7 Learners)

16 (D) Three gas molecules on the left and four on the right. So the product has more gas molecules and prefers a bigger volume to produce a lower pressure.

Endothermic reaction ($\Delta H > 0$) produces cold and must be heated.

17 (D) The equilibrium equation describes the change in the reactants which causes a certain change in the products.

Both X and B changed by two units. C only changed by one unit.

18 (A) There are an equal number of gas molecules (two) on both sides of the equation.

19 (A) Three dihydrogen molecules produce two ammonia molecules.

20 (B) The products form and break up at the same rate.

21 (D) Exothermic reaction ($\Delta H < 0$) produces heat and must be cooled. Equation has 3 gas molecules on the left and only 2 on the right.

Fewer product molecules favours a high pressure.

22 (A) High temperature lowers the yield a little but it increases the rate a lot. Smaller quantities of ammonia are produced, but at a much faster rate.

23 (A) Increasing the concentration of the reactants will increase both the rate and the yield of a reaction.

24 (C) After cooling, reactants increase. So the reverse reaction is favoured and has to be exothermic.

Thus the forward reaction is endothermic

25 (i) (B) A catalyst makes this step in the rate graph as it increases both forward and reverse rates.

(ii) (A) Dotted line (product) suddenly drops.

26 (A) Products increase after heating, so the forward reaction is endothermic.

27 (B) Endothermic reaction ($\Delta H > 0$) produces cold and HI as products. Products (dotted line) decreases which means that the reverse reaction is favoured. Thus cold is excess and the reaction was cooled.

28 (i) (D) Reactions are reversible at equilibrium as both reactants and products form and break up at the same rate.

(ii) (B) Forward reaction is favoured as long as the products are forming at an increasing rate.

(iii) (D) Forward and reverse reactions happen at the same rate once equilibrium has been reached at t_1 .

(iv) (A) Nowhere on this graph do the reactants increase as the products decrease.

29 (B) Heating increases the rate of both the forward and reverse reactions. Forward reaction is endothermic and produces more products when heated.

30 (i) (A) (ii) (C)

31 (A) standard concentrations are $1 \text{ mol} \cdot \text{dm}^{-3}$.

Zinc dissolves as $\text{Zn} - 2 \text{e}^- \rightarrow \text{Zn}^{2+}$

and the Zn^{2+} concentration increases.

Cu^{2+} ions precipitate out as

$\text{Cu}^{2+} + 2 \text{e}^- \rightarrow \text{Cu}$ and thus the concentration of

Cu^{2+} decreases.

The concentrations change rapidly at the start, then they slow down as the zinc dissolves away.

32 (B) P and R increase and thus are products. Reactants Q and S decrease.

33 (D) Endothermic reaction produces cold as a product. Cooling it creates excess cold which favours the reverse reaction.

34 (B) Raise pressure to increase yield as there are two gas molecules on the right and 5 gas molecules on the left.

35 (D) Catalyst "step" forms as it increases both forward and reverse reaction rates.

36 (A) $\text{Ag}^+ (\text{aq}) + \text{Cl}^- (\text{aq}) \rightarrow \text{AgCl} (\text{s})$.

More NaCl must dissolve to replace the removed Cl^- .

Thus more Na^+ forms.

37. D Same number of molecules on both sides of the equation. So the yield is not affected by pressure. Compression will increase the concentration of any gas.

38 (D) Reverse reaction is favoured to remove excess X_3Y

39 (A) $\text{Ag}^+ + \text{Cl}^- \rightarrow \text{AgCl}$ (a white precipitate).

The precipitate removes Cl^- from the solution, favouring the forward reaction to replace it.

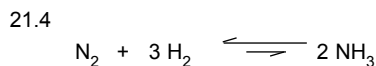
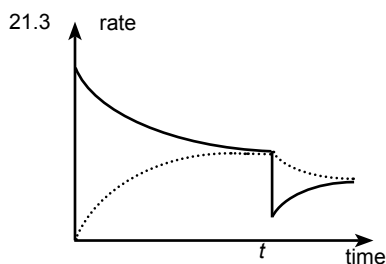
40 (C) Adding Ag^+ removes Cl^- as $\text{AgCl} (\text{s})$ forms.

Reverse reaction is favoured to replace Cl^-

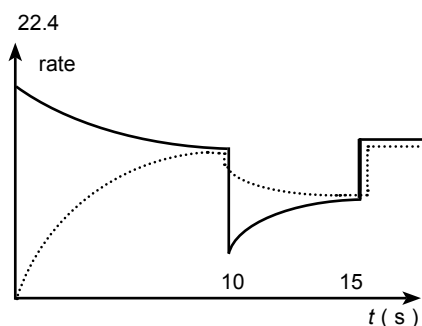
Basic Activities (Level 1 and Level 2 Learners)

- 11.1
- $$\text{C}_2\text{H}_4(\text{g}) + \text{H}_2(\text{g}) \longrightarrow \text{C}_2\text{H}_6(\text{g})$$
- 1 + 1 1
- high pressure
- 11.2
- $$2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \longrightarrow 2\text{SO}_3(\text{g})$$
- 2 + 1 2
- high pressure
- 11.3
- $$\longrightarrow \text{CO}_2(\text{g})$$
- 0 1
- low pressure
- 11.4
- $$\text{H}_2(\text{g}) + \text{I}_2(\text{g}) \longrightarrow 2\text{HI}(\text{g})$$
- 1 + 1 2
- Pressure has no effect on this reaction.
- 12.
- 12.1 Pressure ; temperature ; concentration.
- 12.2 Increase pressure as reverse reaction is favoured to produce fewer molecules.
- Reverse reaction is exothermic, so we must cool the reaction.
- Add more HCl or NH₃ or both.
- To remove this excess, the reverse reaction is favoured.
- 13.
- 13.1 Solution turns purple as the forward exothermic reaction is favoured to produce thermal energy.
- 13.2 Add water drop by drop until solution just turns purple or pink as the forward reaction is favoured to get rid of excess water.
- 13.3
- $$\text{Ag}^+(\text{aq}) + \text{Cl}^-(\text{aq}) \rightarrow \text{AgCl}(\text{s})$$
- and Cl⁻(aq) ions are removed to form a white AgCl precipitate.
- Solution turns a milky purple or milky pink as the forward reaction is favoured to replace the missing Cl⁻ ions.
- 13.4 Solution turns blue favouring the endothermic reverse reaction to produce cooling i.e. remove thermal energy.
- 13.5 Solution turns blue favouring the reverse reaction to get rid of the excess common ion, Cl⁻.
- 13.6 Concentrated H₂SO₄ is a dehydrating agent and absorbs some H₂O. The solution turns blue briefly as the reverse reaction is favoured to replace the water. Then the extra water gained by the acid turns the solution purple again.
- 13.7 No change. The concentrations of liquids and aqueous solutions are unaffected by pressure.
- 14.
- 14.1 The OH⁻ ion becomes a common ion. Solution turns yellow as the forward reaction is favoured to get rid of this excess common ion.

- 14.2 The H^+ ion becomes a common ion. Solution turns orange as the reverse reaction is favoured to get rid of this excess common ion.
- 15.
- $\text{CH}_3\text{COONa(s)} \leftarrow \text{CH}_3\text{COO}^-(\text{aq}) + \text{Na}^+(\text{aq})$
orange red
- The ethanoate ion becomes a common ion. The solution turns brown as the reverse reaction is favoured to get rid of the excess common ion.
- 16.
- 16.1 Colourless. Favour forward reaction to produce a heating effect.
- 16.2 The gas goes brown as the reverse endothermic reaction is favoured to remove thermal energy and produce cold.
- 16.3 Initially the gas goes a darker brown due to its increased concentration. After a short while it gets lighter in colour as the forward reaction is favoured to produce fewer molecules.
- 17.
- 17.1 Heat the reaction ; add a catalyst ; powder the coal ; pressurise the steam.
- 17.2 Heat the endothermic reaction ($\Delta H > 0$) ; decrease the pressure ; increase the concentration of the steam (H_2O).
- 18.
- | | | | | | |
|---|--------------|-----|--------------|----------------------|---------------|
| | H_2 | $+$ | F_2 | $\rightleftharpoons$ | 2HF |
| I | 8 | | 10 | | 0 |
| C | | | | | + 4 |
| E | | | | | 4 |
-
- | | | | | | |
|---|--------------|-----|--------------|----------------------|---------------|
| | H_2 | $+$ | F_2 | $\rightleftharpoons$ | 2HF |
| I | 8 | | 10 | | 0 |
| C | - 2 | | - 2 | | + 4 |
| E | 6 | | 8 | | 4 |
- 6 mol H_2 and 8 mol F_2 and 4 mol HF
- 19.
- | | | | | | |
|---|--------------|-----|----------------|----------------------|-----------------|
| | N_2 | $+$ | 3H_2 | $\rightleftharpoons$ | 2NH_3 |
| I | 6 | | 10 | | 0 |
| C | - 3 | | | | |
| E | 3 | | | | |
-
- | | | | | | |
|---|--------------|-----|----------------|----------------------|-----------------|
| | N_2 | $+$ | 3H_2 | $\rightleftharpoons$ | 2NH_3 |
| I | 6 | | 10 | | 0 |
| C | - 3 | | - 9 | | + 6 |
| E | 3 | | 1 | | 6 |
- 3 mol N_2 and 1 mol H_2 and 6 mol NH_3
-
- 20.
- Some extra dihydrogen was added to the reaction vessel.
- The forward reaction was then favoured to get rid of the excess H_2 .
- 21.
- 21.1 Some dihydrogen was removed from the reaction vessel.
- 21.2
-
- concentration
- N_2
- H_2
- NH_3
- t time



22.
 22.1 $2 \text{HI}(\text{g}) \rightarrow \text{H}_2(\text{g}) + \text{I}_2(\text{g})$
 22.2 Exothermic. Reverse reaction favoured as reactants increase. Cooling favours the exothermic reaction.
 22.3 Cooling lowers the reaction rate of both forward and reverse reactions.



- 22.5 No. The same equilibrium is re-established at a faster rate.

23.
 23.1 forward.
 23.2 4 minutes.
 23.3 Endothermic. Cooling favours the reverse reaction, which is least affected by the cooling, which must thus be exothermic. The forward reaction is then endothermic.
 23.4 A new equilibrium has been established at a lower temperature.

24.
 24.1 $\text{NaCl}(\text{s}) \rightleftharpoons \text{Na}^+(\text{aq}) + \text{Cl}^-(\text{aq})$
 24.2 Fine crystals of $\text{NaCl}(\text{s})$ form as the HCl also provides Cl^- ions. The system removes the excess common Cl^- ion, according to Le Chatelier's principle, by reacting to the disturbed equilibrium to favour the reverse reaction to produce $\text{NaCl}(\text{s})$.

- 24.3 common ion effect.

25.
 25.1 When the equilibrium in a closed system is disturbed, the system will re-instate a new equilibrium by favouring the reaction that will oppose the disturbance.
 25.2 When the rate of dissolving equals the rate of crystallisation.
 The undissolved solute (solid) is in equilibrium with the solution.

- 25.3
 $\text{CH}_3\text{COONa}(\text{s}) \rightarrow \text{CH}_3\text{COO}^-(\text{aq}) + \text{Na}^+(\text{aq})$

- 25.4
 $\text{CH}_3\text{COOH} \rightarrow \text{CH}_3\text{COO}^-(\text{aq}) + \text{H}^+(\text{aq})$
 Both substances form the ethanoate ion. The system gets rid of the excess common ion by favouring the reverse reaction and turning it back into a sodium ethanoate precipitate.
 $\text{CH}_3\text{COONa}(\text{s}) \leftarrow \text{CH}_3\text{COO}^-(\text{aq}) + \text{Na}^+(\text{aq})$

This is the only reaction that can produce a solid.

- 26.1 Haber process.
 26.2 exothermic.
 26.3 Increases yield.
 26.4 Finely divided iron and iron oxide.
 26.5 Increases the rate of the reaction.
 27.
 27.1 Forward reaction is favoured to produce fewer molecules. Yield increases.
 27.2 The forward reaction is exothermic. Heating favours the reverse reaction. Yield decreases.
 27.3 This reaction is exothermic so a lower temperature produces a higher yield but at a much slower rate. Thus production is unprofitable. A smaller yield at the faster rate of the higher temperature is more profitable.
 28.
 28.1 The yield is lower but raising the temperature increases the rate. The lower yield is produced much faster and in practice, this is more profitable.
 28.2 Rate : how fast reactants turn into products.
 Yield : the amount of products formed compared to the amount of uncombined reactants.
 29.
 29.1 decreases 29.2 increases
 29.3 increases
 29.4 no effect / unchanged
 A catalyst does not increase the yield it only increases the rate of the reaction

30.
 30.1 decreases 30.2 increases
 30.3 250 – 600 atmospheres at
 200°C.
 30.4 temperature
 30.5 250 atmospheres at 200°C.
 30.6 The yield is the same from 250 to 600
 atmospheres. Lower pressure is safer (less
 chance of an explosion) and cheaper
 (smaller compressors, thinner tubing, less
 expensive welding of pipe joints).

31.
 31.1 A reversible reaction in which reactants
 form products and the products are continu-
 ally breaking up to reform
 reactants at the same rate.
 31.2 The products are continually forming
 and breaking up.
 31.3 increases.
 31.4 exothermic forward reaction.
 31.5 sulfur trioxide.
 31.6 $\text{SO}_3 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_4$
 31.7 Does not affect the amount of yield, it
 produces the same yield faster.
 31.8 vanadium(V) oxide V_2O_5 .
 31.9 Reactants and products are all gases
 (the same phase).

31.
 31.10 Cool the reaction ;
 increase pressure ;
 increase concentration of reactants ;
 decrease concentration of products.
 31.11 H_2SO_4
 31.12 Used as the electrolyte in motor car
 batteries.

32.
 32.1 Homogeneous means all the
 reactants are in the same phase (gases).
 32.2
 $2 \text{SO}_3(\text{g}) \rightarrow 2 \text{SO}_2(\text{g}) + \text{O}_2(\text{g})$
 32.3 6 minutes
 32.4 Increase the temperature (the for-
 ward reaction is favoured by heating an
 endothermic reaction).
 32.5 At a higher temperature more
 molecules have energy above the
 activation energy. Thus the reaction rate
 for the forward and reverse reactions
 occurs faster.
 32.6 Decrease (the reverse reaction is
 favoured to form fewer molecules).

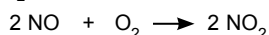
33.
 33.1 The system reached equilibrium.
 33.2 Some A_2 was added at time t .
 The system reduced this excess by using up
 some A_2 and B_2 to form more AB, until a
 new equilibrium was established.
 33.3 The concentrations of the reactants get
 less as they are used up.
 33.4 Two moles of product are formed for
 each mole of reactant that is used up.

34.1 This is an endothermic reaction. A
 hotter engine favours the forward reaction to
 generate a greater cooling effect.
 This produces more of the NO pollutant
 34.2 This is an endothermic reaction.
 Lowering the temperature would favour
 the reverse reaction to generate a greater
 heating effect. This would produce less NO
 pollution and the extra O_2 that is produced
 would aid the catalytic converter to get rid of
 more pollutants.

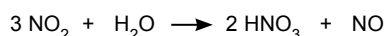
35.
 N_2 has a triple bond which is extremely
 strong. It requires a very high activation
 energy before it can react.
 The molecules have to move extremely fast
 which is only possible at a high temperature.
 NO has much weaker bonds and thus
 requires a much lower activation energy to
 react with O_2 .

36.
 36.1 To turn ammonia into nitric acid.
 36.2 Three
 36.3 The catalytic oxidation of ammonia at
 900°C and 7 atmospheres pressure using
 an alloy of platinum with 10 % rhodium as
 a catalyst. in order to make NO.
 $4 \text{NH}_3 + 5 \text{O}_2 \rightarrow 4 \text{NO} + 6 \text{H}_2\text{O}$

36.3
 N_2 has a very strong triple bond and it
 has a very high activation energy that
 requires a very high temperature to break.
 It is easier to work with ammonia that has
 much weaker bonds that break at a lower
 temperature. High temperatures in industry
 are very expensive.
 36.4 cooling and oxidising
 Cool to 25°C and mix NO with air to
 form NO_2 .



36.5 Dissolve NO_2 in water to make nitric
 acid.



36.6 Making fertilizers and explosives.
 36.7.1 Fertilizers are essential for growing
 enough food.
 Explosives are used by miners and for
 blasting out tunnels, harbours etc.
 36.7.2 Fertilizer runoffs during rain place
 too many nitrates in rivers and dams which
 cause too much growth of water plants,
 algae etc.
 Explosives are used to kill people.

	H_2	+	F_2	$\rightleftharpoons$	2HF
initial	6		8		0 mol
change					+ 6 mol
equilibrium					6 mol

	H_2	+	F_2	$\rightleftharpoons$	2HF
initial	6		8		0 mol
change	- 3		- 3		+ 6 mol
equilibrium	3		5		6 mol

equilibrium	$\frac{3}{1}$		$\frac{5}{1}$		$\frac{6}{1}$
concentration					
	= 3		5		$6 \text{ mol} \cdot \text{dm}^{-3}$

	CaCO_3	$\rightleftharpoons$	CaO	+	CO_2
initial	6		0		0 mol
change			+ 4		mol
equilibrium			4		mol

	CaCO_3	$\rightleftharpoons$	CaO	+	CO_2
initial	6		0		0 mol
change	- 4		+ 4		+ 4 mol
equilibrium	4		4		

- ignore the concentration of solids as
 their densities do not change

$$\text{CaCO}_3(\text{s}) \rightleftharpoons \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$$

equilibrium concentration	$\frac{4}{2}$
	= $2 \text{ mol} \cdot \text{dm}^{-3}$

- only the densities of gases respond to
 change, because they fill the whole
 container
- ignore the densities of solids and
 liquids as they only occupy a portion of
 the reaction vessel

concentration of $\text{CO}_2 = 2 \text{ mol} \cdot \text{dm}^{-3}$

	C	+	O_2	$\rightleftharpoons$	CO_2
initial	8		9		3 mol
change	- 4 mol				
equilibrium	4 mol				

	C	+	O_2	$\rightleftharpoons$	CO_2
initial	8		9		3 mol
change	- 4		- 4		+ 4 mol
equilibrium	4		5		7 mol

- ignore the concentrations of
 solids and liquids

	$\text{C}(\text{s})$	+	$\text{O}_2(\text{g})$	$\rightleftharpoons$	$\text{CO}_2(\text{g})$
equilibrium			$\frac{5}{5}$		$\frac{7}{5}$
concentration					
	=		1		$1,4 \text{ mol} \cdot \text{dm}^{-3}$

1. C
 - 2.1.1 decreases
 - 2.1.2 increases
 - 2.2 Acid adds more H^+ ions. These combine with water to form H_3O^+ ions.
$$\text{H}^+ + \text{H}_2\text{O} \rightarrow \text{H}_3\text{O}^+$$
The H_3O^+ ions thus create an excess. The system responds to the disturbance by reducing the excess which thus favours the reverse reaction to produce the colourless phenolphthalein.
3. A Has fewer product molecules than reactant molecules.
 - 4.1.1 The system reached equilibrium.
 - 4.1.2 Concentration of H_2 was increased OR some H_2 was added at t_1 .
The concentration of HI then increased as more HI was formed while some H_2 and I_2 were used up until equilibrium was re-established at t_2 .
 - 4.2.1 Use oxygen masks OR carry an extra supply of oxygen.
 - 4.2.2 An increase in oxygen concentration will disturb the equilibrium to favour the forward reaction i.e. more HbO_2 molecules in the blood. Hence more oxygen will be transported to the tissues minimising the threat of hypoxia.
- 5.1 Concentrations of products and reactants are constant.
OR Rate of forward reaction = rate of reverse reaction
- 5.2 If sulphur dioxide reacts with oxygen... in a **closed** container, equilibrium can be reached after a while.
6. C
7.
The reaction is exothermic.
Lowering the temperature favours a higher yield of ammonia, but the rate of the reaction is drastically reduced.
Production is unprofitable.
A low temperature may not even have enough energy to overcome the activation energy in which case the reaction will not even start.
8.
 - 8.1 Dynamic (writing "Chemical equilibrium" gets no marks)
 - 8.2 Homogeneous
 - 8.3 True
9.
 - 9.1 The system is in equilibrium and the amounts or concentration remain constant.
 - 9.2 The amount of ammonia was increased when ammonia was added.
 - 9.3 When the concentration of NH_3 is increased, the reverse reaction is favoured because this reaction decreases the excess NH_3 .
The result is an increase in the concentration of H_2 and N_2 until a new equilibrium is established.
10. C
There are fewer white spheres of A at 500 K.
Thus the reverse reaction is favoured when we heat an exothermic reaction.
11.
 - 11.1 The high temperature will favour the forward endothermic reaction and more NO(g) is formed.
 - 11.2 11.2.1 No effect
11.2.2 No effect

12.1

N_2 and O_2 only combine at high temperatures to form NO as the very strong triple bond $N \equiv N$ has to be broken first. The NO rapidly combines with O_2 in the air to form NO_2 . Burning petrol and diesel in internal combustion engines in cars, ships and aeroplanes. The combustion of coal and oil at electric power plants. NO_2 is even formed by burning fuel in heaters and cookers.

Tobacco smoke contains NO_2 .

12.2 $3 NO_2(g) + H_2O(l) \rightarrow 2 HNO_3(aq) + NO$ This is the third line of the Ostwald process

12.3 NO_2 is very soluble and dissolves in rain water to form nitric acid. This nitric acid will damage the crops that the acid rain falls onto. The acid rain increases the acidity of the soil which also inhibits plant growth.

12.4 From the table of reduction potentials.



Cu is above NO_2 on the table and thus it is a stronger reducing agent.

NO_3^- is below Cu^{2+} and thus it is a stronger oxidising agent.

There is a spontaneous reaction between the stronger reducing agent Cu (s) and the stronger oxidising agent NO_3^- (aq) as $E_{cell}^{\theta} > 0$.

However, H^+ is above Cu^{2+} and is thus a weaker oxidising agent.

Cu is below H_2 and is thus a weaker reducing agent.

There is no spontaneous reaction between the weaker reducing agent Cu^{2+} (aq) and the weaker oxidising agent H^+ (aq) in the acid HCl.

	$2 NO_2(g)$	$N_2O_4(g)$
Initial amount	2	x
Changed amount	- 1,2	0,6
Equilibrium amount	0,8	x + 0,6
Equilibrium concentration	0,4	$\frac{x + 0,6}{2}$

$$K_c = \frac{[N_2O_4]}{[NO_2]^2} \quad 2 = \frac{x + 0,6}{(0,4)^2} \quad \text{Thus } (4)(0,16) = x + 0,6$$

$$0,64 = x + 0,6$$

$$x = 0,04 \text{ mol}$$

12.5.2 decreases

12.5.3 According to Le Chatelier's principle, the high pressure favours the forward reaction to produce fewer molecules.

13. Chemical equilibrium OR Dynamic equilibrium

14. D

15.

15.1 Increases

15.2 Decreases

16. B

17.

17.1 A

17.2 Dynamic chemical equilibrium

17.3 D

18.

18.1 The concentration of nitrogen is increased. / More nitrogen was added.

18.2 The pressure on the system is increased.

18.3 The temperature is increased.

18.4 t_1 and t_2

19.

19.1 When the equilibrium in a closed system is disturbed, the system will re-instate a new equilibrium by favouring the reaction that will oppose the disturbance.

19.2 Decreases. When the pressure is increased the reverse reaction is favoured as it produces the smaller number of moles or volume of gas.

19.3 Products form at faster rate. Thus an increase in rate as more effective collisions per unit time occur. Higher yield of products as the endothermic forward reaction is favoured.