**IB Chemistry – SL**

**Topic 7 Questions**

**1.** I2(g) + 3Cl2(g)  2ICl3(g)

What is the equilibrium constant expression for the reaction above?

A. *K*c = 

B. *K*c = 

C. *K*c = 

D. *K*c = 

**2.** 2SO2(g) + O2 (g)  2SO3(g) ∆H~~ο~~ = –200 kJ

According to the above information, what temperature and pressure conditions produce the greatest amount of SO3?

|  |  |  |
| --- | --- | --- |
|  | **Temperature** | **Pressure** |
| A. | low | low |
| B. | low | high |
| C. | high | high |
| D. | high | low |

**3.** Which statement(s) is/are true for a mixture of ice and water at equilibrium?

I. The rates of melting and freezing are equal.

II. The amounts of ice and water are equal.

III. The same position of equilibrium can be reached by cooling water and heating ice.

A. I only

B. I and III only

C. II only

D. III only

**4.** What will happen to the position of equilibrium and the value of the equilibrium constant when the temperature is increased in the following reaction?

Br2(g) + Cl2(g)  2BrCl(g) ∆*H* = +14 kJ

|  |  |  |
| --- | --- | --- |
|  | **Position of equilibrium** | **Value of equilibrium constant** |
| A. | Shifts towards the reactants | Decreases |
| B. | Shifts towards the reactants | Increases |
| C. | Shifts towards the products | Decreases |
| D. | Shifts towards the products | Increases |

**5.** Which statement concerning a chemical reaction at equilibrium is **not** correct?

A. The concentrations of reactants and products remain constant.

B. Equilibrium can be approached from both directions.

C. The rate of the forward reaction equals the rate of the reverse reaction.

D. All reaction stops.

**6.** In the reaction below

N2(g) + 3H2(g)  2NH3(g) ∆*H* = –92 kJ

which of the following changes will increase the amount of ammonia at equilibrium?

I. Increasing the pressure

II. Increasing the temperature

III. Adding a catalyst

A. I only

B. II only

C. I and II only

D. II and III only

**7.** In the Haber process for the synthesis of ammonia, what effects does the catalyst have?

|  |  |  |
| --- | --- | --- |
|  | **Rate of formation of NH3(g)** | **Amount of NH3(g) formed** |
| A. | Increases | Increases |
| B. | Increases | Decreases |
| C. | Increases | No change |
| D. | No change | Increases |

**8.** What will happen if CO2(g) is allowed to escape from the following reaction mixture at equilibrium?

CO2(g) + H2O(l)  H+(aq) + HCO3–(aq)

A. The pH will decrease.

B. The pH will increase.

C. The pH will remain constant.

D. The pH will become zero.

**9.** Which statements are correct for a reaction at equilibrium?

I. The forward and reverse reactions both continue.

II. The rates of the forward and reverse reactions are equal.

III. The concentrations of reactants and products are equal.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

**10.** The manufacture of sulfur trioxide can be represented by the equation below.

2SO2(g) + O2(g)  2SO3(g) ∆*H*~~ο~~ = –197 kJ mol–1

What happens when a catalyst is added to an equilibrium mixture from this reaction?

A. The rate of the forward reaction increases and that of the reverse reaction decreases.

B. The rates of both forward and reverse reactions increase.

C. The value of ∆*H*~~ο~~ increases.

D. The yield of sulfur trioxide increases.

**11.** Which changes will shift the position of equilibrium to the right in the following reaction?

2CO2(g)  2CO(g) +O2(g)

I. adding a catalyst

II. decreasing the oxygen concentration

III. increasing the volume of the container

A. I and II only B. I and III only

C. II and III only D. I, II and III

**12.** Which statement is always true for a chemical reaction that has reached equilibrium?

A. The yield of product(s) is greater than 50.

B. The rate of the forward reaction is greater than the rate of the reverse reaction.

C. The amounts of reactants and products do not change.

D. Both forward and reverse reactions have stopped.

**13.** The equation for a reversible reaction used in industry to convert methane to hydrogen is shown below.

CH4(g) + H2O(g)  CO(g) + 3H2(g) *H*Ө = +210 kJ

Which statement is always correct about this reaction when equilibrium has been reached?

A. The concentrations of methane and carbon monoxide are equal.

B. The rate of the forward reaction is greater than the rate of the reverse reaction.

C. The amount of hydrogen is three times the amount of methane.

D. The value of *H*Ө for the reverse reaction is –210 kJ.

**14.** The equation for a reaction used in the manufacture of nitric acid is

4NH3(g) + 5O2(g)  4NO(g) + 6H2O(g) *H*Ө = –900 kJ

Which changes occur when the temperature of the reaction is increased?

|  |  |
| --- | --- |
| Position of equilibrium | Value of *K*c |
| A. | shifts to the left | increases |
| B. | shifts to the left | decreases |
| C. | shifts to the right | increases |
| D. | shifts to the right | decreases |

**15.** Which changes cause an increase in the equilibrium yield of SO3(g) in this reaction?

2SO2(g) + O2(g)  2SO3(g) *H*Ө = –196 kJ

I. increasing the pressure

II. decreasing the temperature

III. adding oxygen

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

**16.** Iron(III) ions react with thiocyanate ions as follows.

Fe3+(aq) + CNS–(aq)  Fe(CNS)2+(aq)

What are the units of the equilibrium constant, *K*c, for the reaction?

A. mol dm–3

B. mol2 dm–6

C. mol–1 dm3

D. mol–2 dm6

**17.** Consider the following equilibrium reaction in a closed container at 350C.

SO2(g) + Cl2(g)  SO2Cl2(g) *H*Ө = 85 kJ

Which statement is correct?

A. Decreasing the temperature will increase the amount of SO2Cl2(g).

B. Increasing the volume of the container will increase the amount of SO2Cl2(g).

C. Increasing the temperature will increase the amount of SO2Cl2(g).

D. Adding a catalyst will increase the amount of SO2Cl2(g).

**18.** Which of the following equilibria would **not** be affected by pressure changes at constant temperature?

A. 4HCl(g) + O2(g)  2H2O(g) + 2Cl2(g)

B. CO(g) + H2O(g)  H2(g) + CO2(g)

C. C2H4(g) + H2O(g)  C2H5OH(g)

D. PF3Cl2(g)  PF3(g) + Cl2(g)

**19.** Consider the following equilibrium reaction in a closed container at 350°C

SO2(g) + Cl2(g)  SO2Cl2(g) *H*Ө = 85 kJ

Which statement is correct?

A. Decreasing the temperature will increase the amount of SO2Cl2(g).

B. Increasing the volume of the container will increase the amount of SO2Cl2(g).

C. Increasing the temperature will increase the amount of SO2Cl2(g).

D. Adding a catalyst will increase the amount of SO2Cl2(g).

**20.** What is the equilibrium constant expression, *K*c, for the reaction below?

N2(g) + 2O2(g)  2NO2(g)

A. *K*c = 

B. *K*c = 

C. *K*c = 

D. *K*c = 

**21.** Sulfur dioxide and oxygen react to form sulfur trioxide according to the equilibrium.

2SO2(g) + O2(g)  2SO3(g)

How are the amount of SO3 and the value of the equilibrium constant for the reaction affected by an increase in pressure?

A. The amount of SO3 and the value of the equilibrium constant both increase.

B. The amount of SO3 and the value of the equilibrium constant both decrease.

C. The amount of SO3 increases but the value of the equilibrium constant decreases.

D. The amount of SO3 increases but the value of the equilibrium constant does not change.

**22.** The equation for the Haber process is:

N2(g) + 3H2(g)  2NH3(g) *H*Ө = 92.2 kJ

Which conditions will favour the production of the greatest amount of ammonia at equilibrium?

A. High temperature and high pressure

B. High temperature and low pressure

C. Low temperature and high pressure

D. Low temperature and low pressure

**23.** The sequence of diagrams represents the system as time passes for a gas phase reaction in which reactant **X** is converted to product **Y**.



Which statement is correct?

A. At *t* = 5 days the rate of the forward reaction is greater than the rate of the backward reaction.

B. At *t* = 7 seconds the reaction has reached completion.

C. At *t* = 10 minutes the system has reached a state of equilibrium.

D. At *t* = 5 days the rate of the forward reaction is less than the rate of the backward reaction.

**24.** What changes occur when the temperature is increased in the following reaction at equilibrium?

Br2(g) + Cl2(g)  2BrCl(g) ∆*H*~~ο~~ = +14 kJ mol–1

|  |  |  |
| --- | --- | --- |
|  | **Position of equilibrium** | **Value of equilibrium constant** |
| A. | Shifts towards the reactants | Decreases |
| B. | Shifts towards the reactants | Increases |
| C. | Shifts towards the products | Decreases |
| D. | Shifts towards the products | Increases |

**25.** The table below gives information about the percentage yield of ammonia obtained in the Haber process under different conditions.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Pressure/** |  | **Temperature/**°**C** | |  |
| **atmosphere** |  |  | |  |
|  | **200** | **300** | **400** | **500** |
| **10** | 50.7 | 14.7 | 3.9 | 1.2 |
| **100** | 81.7 | 52.5 | 25.2 | 10.6 |
| **200** | 89.1 | 66.7 | 38.8 | 18.3 |
| **300** | 89.9 | 71.1 | 47.1 | 24.4 |
| **400** | 94.6 | 79.7 | 55.4 | 31.9 |
| **600** | 95.4 | 84.2 | 65.2 | 42.3 |

(a) From the table, identify which combination of temperature and pressure gives the highest yield of ammonia.

……………………………………………………………………………………….

(1)

(b) The equation for the main reaction in the Haber process is

N2(g) + 3H2(g)  2NH3(g) ∆*H* is negative

Use this information to state and explain the effect on the yield of ammonia of increasing

(i) pressure: …………………………….………………………………………..

……………………………………………………………..………………….

………………………………………………………………………………..

(2)

(ii) temperature: ………………………………………………………………….

…………………………………………………………………………….….

………………………………………………………………………………..

………………………………………………………………………………..

(2)

(c) In practice, typical conditions used in the Haber process are a temperature of 500 °C and a pressure of 200 atmospheres. Explain why these conditions are used rather than those that give the highest yield.

……………………………………………………………………………………….

……………………………………………………………………………………….

(2)

(d) Write the equilibrium constant expression, *K*c, for the production of ammonia.

……………………………………………………………………………………….

……………………………………………………………………………………….

(1)

(Total 8 marks)

**26.** Consider the following equilibrium reaction.

2 SO2(g) + O2(g)  2SO3(g) ∆*H* = –198 kJ

Using Le Chatelier’s Principle, state and explain what will happen to the position of equilibrium if

(a) the temperature increases.

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(2)

(b) the pressure increases.

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(2)

(Total 4 marks)

**27.** Ammonia is produced by the Haber process according to the following reaction.

N2(g) + 3H2(g)  2NH3(g) *H* is negative

(a) State the equilibrium constant expression for the above reaction.

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(1)

(b) Predict, giving a reason, the effect on the position of equilibrium when the pressure in the reaction vessel is increased.

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(2)

(c) State and explain the effect on the value of *K*c when the temperature is increased.

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(2)

(d) Explain why a catalyst has no effect on the position of equilibrium.

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(1)

(Total 6 marks)

**28.** (a) The following equilibrium is established at 1700°C.

CO2 (g) + H2 (g)  H2O (g) + CO (g)

If only carbon dioxide gas and hydrogen gas are present initially, sketch on a graph a line representing rate against time for (i) the forward reaction **and** (ii) the reverse reaction until shortly after equilibrium is established. Explain the shape of each line.

(7)

(b) *K*c for the equilibrium reaction is determined at two different temperatures. At 850°C,   
*K*c = 1.1 whereas at 1700°C, *K*c= 4.9.

On the basis of these *K*c values explain whether the reaction is exothermic or endothermic.

(3)

(Total 10 marks)

**29.** The equation for one reversible reaction involving oxides of nitrogen is shown below:

N2O4(g)  2NO2(g) *H*Ө = +58 kJ

Experimental data for this reaction can be represented on the following graph:



(i) Write an expression for the equilibrium constant, *K*c, for the reaction. Explain the significance of the horizontal parts of the lines on the graph. State what can be deduced about the magnitude of *K*c for the reaction, giving a reason.

(4)

(ii) Use Le Chatelier’s principle to predict and explain the effect of increasing the temperature on the position of equilibrium.

(2)

(iii) Use Le Chatelier’s principle to predict and explain the effect of increasing the pressure on the position of equilibrium.

(2)

(iv) State and explain the effects of a catalyst on the forward and reverse reactions, on the position of equilibrium and on the value of *K*c.

(6)

(Total 14 marks)

**30.** Consider the following reaction in the Contact process for the production of sulfuric acid for parts (a) to (d) in this question.

2SO2 + O2  2SO3

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

(1)

(b) (i) State the catalyst used in this reaction of the Contact process.

(1)

(ii) State and explain the effect of the catalyst on the value of the equilibrium constant and on the rate of the reaction.

(4)

(c) Use the collision theory to explain why increasing the temperature increases the rate of the reaction between sulfur dioxide and oxygen.

(2)

(d) Using Le Chatelier’s principle state and explain the effect on the position of equilibrium of

(i) increasing the pressure at constant temperature.

(2)

(ii) removing of sulfur trioxide.

(2)

(iii) using a catalyst.

(2)

(Total 14 marks)

**31.** Consider the following reaction in the Contact process for the production of sulfuric acid for parts (a) to (c) in this question.

2SO2 + O2  2SO3

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

(1)

(b) (i) State the catalyst used in this reaction of the Contact process.

(1)

(ii) State and explain the effect of the catalyst on the value of the equilibrium constant and on the rate of the reaction.

(4)

(c) Using Le Chatelier’s principle explain the effect on the position of equilibrium of

(i) increasing the pressure at constant temperature.

(2)

(ii) removing sulfur trioxide.

(2)

(Total 10 marks)

**32.** Many reversible reactions in industry use a catalyst. State and explain the effect of a catalyst on the position of equilibrium and on the value of *K*c.

(Total 4 marks)

**33.** The equation for a reaction used in industry is

CH4(g) + H2O(g)  3H2(g) + CO(g) *H*Ө = +210 kJ

Deduce the equilibrium constant expression, *K*c, for this reaction.

(Total 1 mark)

**34.** Consider the following reaction where colourless bromide ions react with colourless hydrogen peroxide to form a red-brown bromine solution.

2Br–(aq) + H2O2(aq) + 2H+(aq)  Br2(aq) + 2H2O(l) *H* = negative

(a) Predict and explain the effect on the **position of equilibrium** when

(i) a small amount of sodium bromide solution is added.

(2)

(ii) a small amount of sodium hydroxide solution is added.

(2)

(iii) a catalyst is added.

(2)

(b) State and explain the effect on the value of the **equilibrium constant** when the temperature of the reaction is increased.

(2)

(c) State and explain the colour change when hydrochloric acid is added to the reaction solution at equilibrium.

(3)

(Total 11 marks)

**35.** The equation for the exothermic reaction in the Contact process is given below:

2SO2(g) + O2(g)  2SO2(g)

(i) Write the equilibrium constant expression for the reaction.

(1)

(ii) State and explain qualitatively the pressure and temperature conditions that will give the highest yield of sulfur trioxide.

(4)

(iii) In practice, conditions used commercially in the Contact process are 450°C and 2 atmospheres of pressure. Explain why these conditions are used rather than those that give the highest yield.

(3)

(iv) Name a catalyst used in the Contact process. State and explain its effect on the value of the equilibrium constant.

(3)

(Total 11 marks)

**36.** In the gaseous state, methane and steam react to form hydrogen and carbon dioxide.

(i) Write an equation for the endothermic equilibrium reaction. Deduce the equilibrium expression for the reaction and state its units.

(4)

(ii) Deduce and explain the conditions of temperature and pressure under which the forward reaction is favoured.

(4)

(iii) Explain, at the molecular level, why the reaction is carried out at high pressure in industry.

(2)

(Total 10 marks)

**37.** The diagrams below represent equilibrium mixtures for the reaction Y + X2  XY + X at 350 K and 550 K respectively. Deduce and explain whether the reaction is exothermic or endothermic.



(Total 2 marks)

**38.** The equation for the main reaction in the Haber process is:

N2(g) + 3H2(g)  2NH3(g) ∆*H* is negative

(i) Determine the equilibrium constant expression for this reaction.

(1)

(ii) State and explain the effect on the equilibrium yield of ammonia with increasing the pressure and the temperature.

(4)

(iii) In practice, typical conditions used in the Haber process involve a temperature of 500°C and a pressure of 200 atm. Explain why these conditions are used rather than those that give the highest yield.

(2)

(iv) At a certain temperature and pressure, 1.1 dm3 of N2(g) reacts with 3.3 dm3 of H2(g). Calculate the volume of NH3(g), that will be produced.

(1)

(v) Suggest why this reaction is important for humanity.

(1)

(vi) A chemist claims to have developed a new catalyst for the Haber process, which increases the yield of ammonia. State the catalyst normally used for the Haber process, and comment on the claim made by this chemist.

(2)

(Total 11 marks)

**IB Chemistry – SL**

**Topic 7 Answers**

**1.** D

**2.** B

**3.** B

**4.** D

**5.** D

**6.** A

**7.** C

**8.** B

**9.** A

**10.** B

**11.** C

**12.** C

**13.** D

**14.** B

**15.** D

**16.** C

**17.** A

**18.** B

**19.** A

**20.** C

**21.** D

**22.** C

**23.** C

**24.** D

**25.** (a) 200°C 600 atm. *(both for* ***[1]****, units not needed);* 1  
*allow the “highest pressure and the lowest temperature”*

(b) (i) yield increases/equilibrium moves to the right/more ammonia; 2  
4 (gas) molecules → 2/decrease in volume/fewer molecules on right hand side;

(ii) yield decreases/equilibrium moves to the left/less ammonia;  
exothermic reaction/*OWTTE*; 2

(c) high pressure expensive/greater cost of operating at high pressure/reinforced  
pipes *etc*. needed;  
lower temperature – greater yield, but **lowers** rate; 2  
*Do not award a mark just for the word “compromise”.*

(d) Kc =  *(ignore units)*; 1

[8]

**26.** (a) (position of) equilibrium shifts to the left/towards reactants; (forward)  
reaction is exothermic/∆*H* is negative/the reverse reaction is  
endothermic/*OWTTE*;2

Do not accept “Le Chatelier’s Principle” without some additional explanation.

(b) (position of) equilibrium shifts to the right/towards products;   
fewer gas molecules on the right hand side/volume decreases in forward   
reaction/*OWTTE*; 2

Do not accept “Le Chatelier’s Principle” without some additional explanation.

[4]

**27.** (a)  1

Do not allow round brackets unless Kp is used.

(b) equilibrium shifts to the right/products;

4 mol  2 mol of gas/fewer moles of gas on the right/products; 2

(c) *Kc* decreases;

equilibrium position shifts to the left/reactants/forward reaction is exothermic  
/reverse reaction is endothermic; 2

(d) catalyst increases the rate of the forward and backward reactions equally  
/lowers the activation energy of both forward and backward reaction equally  
/lowers *Ea* so rate of forward and backward reactions increase; 1

[6]

**28.** (a)



two curves – one labelled “forward” starting up high up y-axis and one labelled  
“reverse” starting from zero;  
curves merge and become horizontal;  
No penalty for failing to label axes.

*forward reaction:*highest concentration, thus rate high to begin with;  
as reaction proceeds, concentrations decrease, so does rate;

*reverse reaction:*zero rate initially/at t = 0 (since no products present);  
rate increases as concentration of products increases;  
equilibrium established when rate of forward reaction = rate of reverse reaction; 7

(b) (reaction is) endothermic;  
Kc increases with (increasing) temperature;  
forward reaction favoured/heat used up/OWTTE; 3

[10]

**29.** (i) 

(horizontal line) concentration of reactant and product remains constant/equilibrium reached;

(magnitude of) *K*c greater than 1;

Accept 1.6.

product concentration greater than reactant concentration; 4

(ii) increased temperature shifts equilibrium position to right;  
(forward) reaction is endothermic/absorbs heat; 2

(iii) increased pressure shifts equilibrium to left;  
fewer (gas) moles/molecules on left; 2

(iv) both/forward and reverse rates increased/increase in forward reverse  
rates are equal;

activation energy reduced;

position of equilibrium unchanged;

concentration/amount of reactants and products remain constant;

value of *K*c unchanged;

*K*c only affected by changes in temperature; 6

[14]

**30.** (a) *K/Kc* = [SO3]2÷[SO2]2[O2]; 1

Accept correct Kp expression.

(b) (i) vanadium(V) oxide/(di)vanadium pentaoxide/V2O5; 1

Allow just vanadium oxide but not correct formula.

(ii) catalyst does not affect the value of *Kc*;

forward and reverse rates increase equally/by the same factor;

catalyst increases the rate of the reaction;

(by providing an alternative path for the reaction with) lower  
activation energy; 4

(c) more energetic collisions/more molecules have energy greater than  
activation energy;

more frequent collisions; 2

(d) (i) shifts equilibrium position to the products/right;

to the side with fewer gas molecules or moles/lower volume of gas; 2

(ii) shifts equilibrium position to the products/right;

to compensate for loss of SO3/produce more SO3; 2

(iii) no effect;

forward and backward rates increased equally/by the same factor; 2

[14]

**31.** (a) *K / Kc* = [SO3]2÷[SO2]2[O2]; 1

Exactly as written.

Accept correct Kp expression.

(b) (i) vanadium(V) oxide/(di)vanadium pentaoxide/V2O5/Pt; 1

Allow just vanadium oxide but not incorrect formula.

(ii) catalyst does not affect the value of Kc;

forward and reverse rate increase equally/by the same factor;

catalyst increases the rate of the reaction;

(by providing an alternative path for the reaction with) lower  
activation energy; 4

(c) (i) shifts equilibrium position to the products/right;

to the side with least gas molecules or moles/lower volume of gas; 2

(ii) shifts equilibrium position to the products/right;

to compensate for loss of SO3/produce more SO3; 2

[10]

**32.** no effect on position of equilibrium;

forward and reverse reactions speeded up equally/affects the rate of reaction  
but not the extent of the reaction;

no effect on value of *Kc*;

no change in concentrations of reactants or products/*Kc* only changes if  
temperature alters;

[4]

**33.** 

[1]

**34.** (a) (i) shifts to the right/toward products/forward reaction favoured;

to consume excess Br added; 2

Do not accept “due to Le Chatelier’s principle”.

(ii) shifts to the left/toward reactants/reverse reaction favoured;

NaOH reacts to consume H+/an increase in the amount of H2O  
resulting from neutralization; 2

(iii) no effect;

catalyst increases the rate of the forward and backward reactions  
equally/lowers the activation energy of both forward and backward  
reaction equally/lowers EA so rate of forward and backward reactions  
increase equally; 2

(b) equilibrium constant decreases;

forward reaction is exothermic/produces heat/reverse reaction is endothermic  
/absorbs heat; 2

(c) colour change from red-brown to darker red-brown of Br2/red-brown colour  
intensifies/OWTTE;

equilibrium position shifts to the right/products;

to consume H+; 3

[11]

**35.** (i)  1

(ii) pressure  
high pressure (will allow system to occupy smaller volume);

Vproduct <Vreactant/equilibrium moves to the right to reduce pressure  
/reaction proceeds to lower/lowest number of gaseous molecules  
/*OWTTE*;

*Temperature*low temperature;  
(exothermic reaction) forward reaction favoured to replace some  
of the heat removed/equilibrium moves to the right to produce heat  
*/OWTTE;* 4

No mark for just saying “due to Le Chatelier's principle”

(iii) rate is faster at 450C (than at low temperatures);  
>95%/90  99% yield/(very) high conversion takes place;  
unnecessary to use expensive high pressure equipment/(to achieve) high  
pressure is very expensive; 3

(iv) vanadium pentoxide/vanadium(V) oxide/V2O5/finely divided  
platinum/Pt;  
no effect on *Kc*;  
forward and reverse rates speeded up (equally); 3

[11]

**36.** (i) CH4(g) + 2H2O(g)  4H2(g) + CO2(g);

States not required. Award **[1]** for balanced equation and **[1]** for equilibrium sign.

*K*c = ;

units: mol2 dm6/mol2 L2/mol2 l2; do not accept: *M*2 4

(ii) (endothermic reaction) increase in temperature (favours the forward  
reaction);  
absorbs (some of) the heat supplied/*OWTTE*;

Award no marks for saying: “because of Le Chatelier’s principle”.

low pressure (will allow system to occupy more volume);  
Vproduct > Vreactant/reaction proceeds to greater number of gaseous moles  
/molecules/more moles of gases on right/*OWTTE*;

*ECF from (i)* 4

(iii) at high pressure concentration increases/reaction rate faster;  
more frequent collisions; 2

[10]

**37.** less product is present at higher temperatures;  
Therefore the forward reaction is exothermic; 2

[2]

**38.** (i) (*K*c =)  *(ignore units)*; 1

(ii) *Increasing the pressure:*Yield increases/equilibrium moves to the right/more ammonia;  
4 gas molecules → 2/decrease in volume/fewer gas molecules  
on right hand side;

*Increasing the temperature:*Yield decreases/equilibrium moves to the left/less ammonia;  
Exothermic reaction/*OWTTE*; 4

(iii) Higher temperature increases rate;  
Lower pressure is less expensive/lower cost of operating at low  
pressure/reinforced pipes not needed; 2

Do not award a mark just for the word “compromise”.

(iv) 2.2 (dm3); 1

Penalize incorrect units.

(v) Fertilizers/increasing crop yields;  
Production of explosives for mining; 1 max

(vi) Fe/iron;

Allow magnetite/iron oxide.

Claim is not valid since catalysts do not alter the yield/position  
of equilibrium/only increase the rate of reaction; 2

[11]