Cambridge AS & A Level

CHEMISTRY

Paper 1

Topical Past Paper Questions

+ Answer Scheme

2015 - 2021

PapaCambridge

Chapter 7

Equilibria

7.1 Chemical equilibria: reversible reactions, dynamic equilibrium

337. 9701_m22_qp_12 Q: 12

Hydrogen and iodine react to form hydrogen iodide in an exothermic reaction. The equation is shown.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$

A 1 m^3 reaction vessel contains H_2, I_2 and HI gases at equilibrium. The temperature is changed such that the total pressure in the 1 m^3 vessel doubles.

What is the effect on the value of K_p and on the position of equilibrium?

	effect on the value of K_p	effect on the position of equilibrium
A	decreases	moves left
B	increases	moves right
C	no change	moves left
D	no change	no change

---

338. 9701_m22_qp_12 Q: 24

The product of the Contact process is Z.

Which reaction or process leads to the formation of a gas that can neutralise an aqueous solution of Z?

A atmospheric lightning

B combustion of fuel in an internal combustion engine

C the Haber process

D thermal decomposition of Group 2 nitrates

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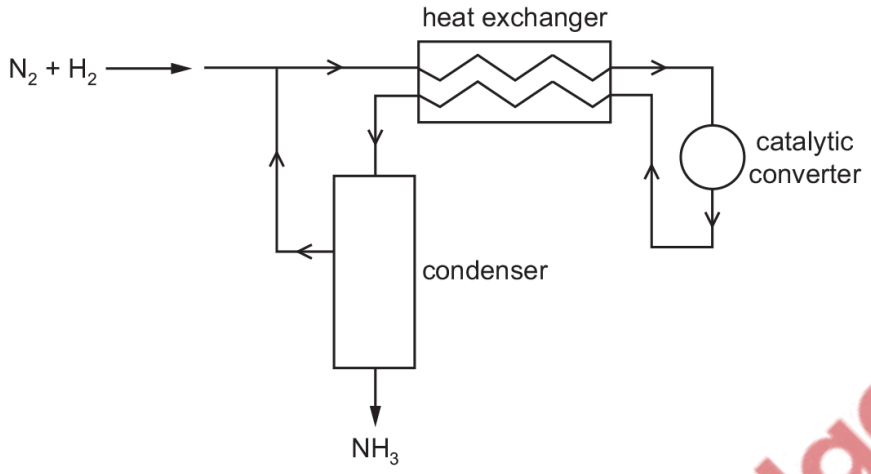
339. 9701_s21_qp_11 Q: 10

The diagram represents the Haber process for the manufacture of ammonia from nitrogen and hydrogen.



What is the purpose of the heat exchanger?

A to cool the incoming gas mixture to avoid overheating the catalyst

B to cool the reaction products and separate the NH_3 from unused N_2 and H_2

C to warm the incoming gas mixture and shift the equilibrium to give more NH_3

D to warm the incoming gas mixture and speed up the reaction

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340. 9701_s21_qp_12 Q: 10

3.60 moles of hydrogen gas and 2.00 moles of iodine vapour are placed in a reaction vessel which is then sealed and maintained at a constant temperature.

The equation for the reaction is shown.

$$H_2 + I_2 \rightleftharpoons 2HI$$

At equilibrium, 3.20 moles of hydrogen remain. All reactants and products are gaseous.

What is the value of K_p under these conditions?

A 0.0313 **B** 0.125 **C** 0.156 **D** 8.00

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341. 9701_s21_qp_13 Q: 9

Copper dissolves in dilute nitric acid producing a blue solution of $Cu(NO_3)_2$, water and nitrogen(II) oxide as the only products.

How many moles of acid react with three moles of copper in the balanced equation?

A 2 **B** 4 **C** 6 **D** 8

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342. 9701_s21_qp_13 Q: 10

Nitrogen reacts with hydrogen to produce ammonia.

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

A mixture of 2.00 mol of nitrogen, 6.00 mol of hydrogen and 2.40 mol of ammonia is allowed to reach equilibrium in a sealed vessel of volume 1 dm^3. It is found that 2.32 mol of nitrogen were present in the equilibrium mixture.

Which expression will give the value of K_c?

A $\dfrac{(1.76)^2}{(2.32)(6.96)^3}$

B $\dfrac{(1.76)^2}{(2.32)(6.32)^3}$

C $\dfrac{(2.08)^2}{(2.32)(6.32)^3}$

D $\dfrac{(2.40)^2}{(2.32)(6.00)^3}$

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343. 9701_s21_qp_13 Q: 11

Nitric acid is produced by oxidising ammonia. The first step is to react ammonia with oxygen in the presence of a catalyst to form nitrogen monoxide.

$$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g) \quad \Delta H = -1636\ kJ\ mol^{-1}$$

Which set of conditions will produce the greatest yield of nitrogen monoxide at equilibrium?

	temperature	pressure
A	high	high
B	high	low
C	low	high
D	low	low

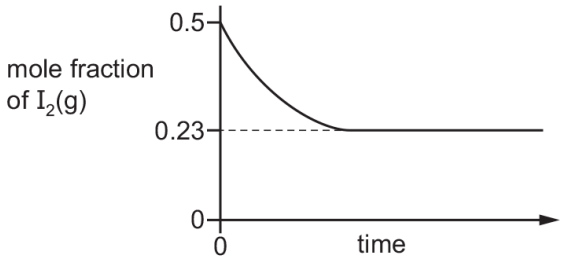
---

344. 9701_w21_qp_11 Q: 10

10 The equation shows that $H_2(g)$ and $I_2(g)$ react to form an equilibrium mixture.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g) \qquad \Delta H^\ominus = -9.6\,kJ\,mol^{-1}$$

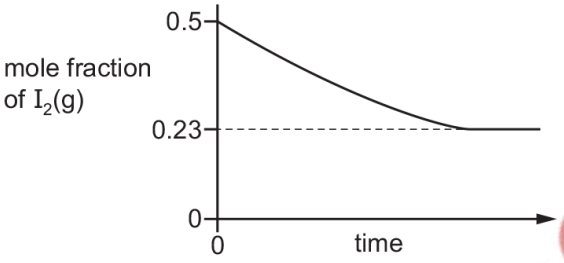
A mixture containing equal amounts of $H_2(g)$ and $I_2(g)$ is made at temperature T_1 and the composition of the mixture is monitored. A graph of the results is shown.



The experiment is repeated at a lower temperature, T_2.

Which new graph would be obtained?

A



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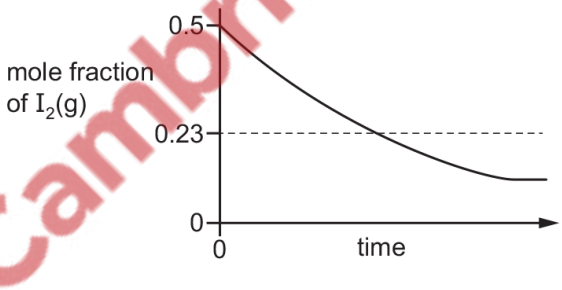

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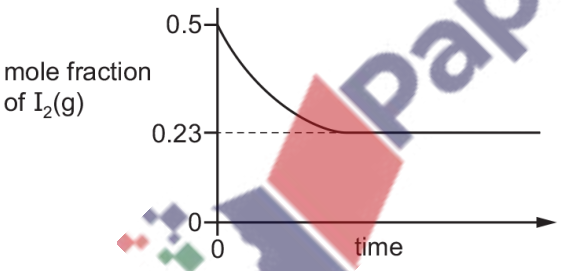

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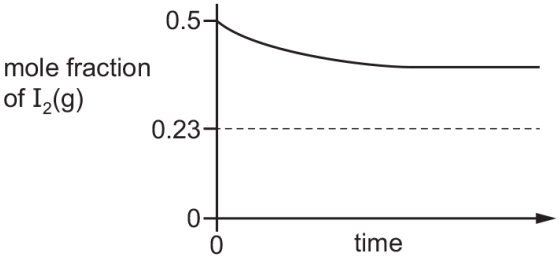

345. 9701_m20_qp_12 Q: 6

The equation for the reaction between silver chloride and aqueous ammonia is shown.

$$AgCl(s) + 2NH_3(aq) \rightleftharpoons [Ag(NH_3)_2]^+(aq) + Cl^-(aq)$$

What are the units of K_c for this reaction?

A no units **B** $mol^{-1}\,dm^3$ **C** $mol\,dm^{-3}$ **D** $mol^2\,dm^{-6}$

346. 9701_m20_qp_12 Q: 11

The main stage in the Contact process is an equilibrium reaction.

$$2SO_2 + O_2 \rightleftharpoons 2SO_3$$

Which row describes the effect of the named condition on the equilibrium yield?

	presence of catalyst	high pressure	high temperature
A	no effect on yield	decreases yield	increases yield
B	no effect on yield	increases yield	decreases yield
C	increases yield	decreases yield	increases yield
D	increases yield	increases yield	decreases yield

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347. 9701_s20_qp_11 Q: 1

Ethene can be oxidised to form epoxyethane, C_2H_4O.

$$C_2H_4(g) + \tfrac{1}{2}O_2(g) \rightleftharpoons C_2H_4O(g) \qquad \Delta H^\ominus = -107\,kJ\,mol^{-1}$$

Which set of conditions gives the greatest yield of epoxyethane at equilibrium?

	pressure	temperature / °C
A	high	100
B	high	200
C	low	100
D	low	200

---

348. 9701_s20_qp_11 Q: 7

What are the units of K_p for the reaction shown?

$$H_2O(g) + C(s) \rightleftharpoons H_2(g) + CO(g)$$

A Pa^{-1} **B** Pa **C** Pa^2 **D** no units

---

349. 9701_s20_qp_12 Q: 3

The catalysed formation of ammonia by the Haber process can be represented by the equation shown.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92\,kJ\,mol^{-1}$$

Which change in conditions will increase both the rate of formation and the equilibrium yield of ammonia?

A decrease in the temperature

B increase in the temperature

C increase in the pressure

D increase in the surface area of the catalyst

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350. 9701_s20_qp_12 Q: 11

PCl_5 decomposes as shown.

$$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$$

1.0 mol of $PCl_5(g)$, 1.0 mol of $PCl_3(g)$ and 1.0 mol of $Cl_2(g)$ are placed in a container of volume 1 dm^3 at 250 °C and allowed to reach equilibrium.

At this temperature, the equilibrium mixture contains 1.8 moles of PCl_3.

What is the value of K_c at 250 °C?

A 1 **B** 1.8 **C** 9 **D** 16.2

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351. 9701_s20_qp_13 Q: 11

Two reactions are shown.

reaction 1 $X_2(g) + Y_2(g) \rightleftharpoons 2XY(g)$

reaction 2 $XY(g) \rightleftharpoons \frac{1}{2}X_2(g) + \frac{1}{2}Y_2(g)$

The equilibrium constant, K_p, for reaction 1 is 0.0052.

What is K_p for reaction 2?

A 2.6×10^{-3} **B** 13.9 **C** 192.3 **D** 384.6

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352. 9701_w20_qp_11 Q: 10

In aqueous solution, sulfuric acid dissociates as shown.

$H_2SO_4 \rightarrow HSO_4^- + H^+$ This reaction goes to completion.

$HSO_4^- \rightleftharpoons SO_4^{2-} + H^+$ This reaction reaches equilibrium with constant K_c.

Analysis of a $2.00\,mol\,dm^{-3}$ solution of H_2SO_4 found the HSO_4^- concentration to be $1.988\,mol\,dm^{-3}$.

What is K_c?

A $1.381 \times 10^5\,dm^3\,mol^{-1}$

B $82.34\,dm^3\,mol^{-1}$

C $1.214 \times 10^{-2}\,mol\,dm^{-3}$

D $7.244 \times 10^{-5}\,mol\,dm^{-3}$

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353. 9701_w20_qp_12 Q: 10

Sulfur dioxide and oxygen react to form sulfur trioxide. The reaction is reversible.

$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$ $K_p = 2.96 \times 10^{-9}\,Pa^{-1}$ at 700 °C

The reaction is allowed to reach equilibrium at 700 °C. The partial pressure of $O_2(g)$ is 375 kPa and the partial pressure of $SO_3(g)$ is 20.3 kPa.

What is the partial pressure of $SO_2(g)$?

A 19.3 kPa **B** 609 kPa **C** 18 300 kPa **D** 609 000 kPa

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354. 9701_w20_qp_12 Q: 11

Ammonia is made by the Haber process. The reactants are nitrogen and hydrogen.

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

What will increase the rate of the forward reaction?

A adding argon to the mixture but keeping the total volume constant

B decreasing the temperature

C increasing the total pressure by reducing the total volume at constant temperature

D removing ammonia as it is made but keeping the total volume of the mixture the same

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355. 9701_w20_qp_12 Q: 14

$AgNO_3(aq)$ is added to a solution of a halide ion, $X^-(aq)$, and aqueous ammonia is then added.

The ionic equations for the two reactions that occur are shown.

$$Ag^+(aq) + X^-(aq) \rightleftharpoons AgX(s) \qquad \text{equilibrium 1}$$

$$Ag^+(aq) + 2NH_3(aq) \rightleftharpoons Ag(NH_3)_2^+(aq) \qquad \text{equilibrium 2}$$

Which statement is correct?

A The position of equilibrium 1 lies to the left when $X^- = I^-$.

B Increasing the concentration of ammonia causes the position of equilibrium 1 to move to the left.

C K_c for equilibrium 2 is larger when $X^- = Cl^-$ than when $X^- = I^-$.

D Equilibrium 2 is a redox reaction.

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356. 9701_m19_qp_12 Q: 11

When copper is added to a solution of silver ions, the following equilibrium is established.

$$Cu(s) + 2Ag^+(aq) \rightleftharpoons Cu^{2+}(aq) + 2Ag(s) \qquad K_c = 1.0 \times 10^5$$

What is the concentration of silver ions at equilibrium when $[Cu^{2+}] = 0.10\,\text{mol dm}^{-3}$?

A $5.0 \times 10^{-7}\,\text{mol dm}^{-3}$

B $5.0 \times 10^{-4}\,\text{mol dm}^{-3}$

C $1.0 \times 10^{-3}\,\text{mol dm}^{-3}$

D $1.0 \times 10^{2}\,\text{mol dm}^{-3}$

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357. 9701_s19_qp_11 Q: 10

Hydrogen iodide gas decomposes reversibly producing iodine vapour and hydrogen.

$$2HI(g) \rightleftharpoons I_2(g) + H_2(g) \qquad \Delta H = +12\,\text{kJ mol}^{-1}$$

The position of the equilibrium for this reaction may be altered by changing the external conditions.

Which row correctly describes the change in position of equilibrium?

	effect of increasing the pressure	effect of increasing the temperature
A	moves to the right	moves to the right
B	moves to the right	moves to the left
C	no change	moves to the right
D	no change	moves to the left

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358. 9701_s19_qp_11 Q: 11

The reaction between sulfur dioxide and oxygen is reversible.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad K_c = 280\,mol^{-1}\,dm^3 \text{ at } 1000\,K$$

In an equilibrium mixture at 1000 K the sulfur trioxide concentration is 6.00 mol dm^{-3}.

The sulfur dioxide concentration is twice the oxygen concentration.

What is the sulfur dioxide concentration?

A 0.175 mol dm^{-3}

B 0.254 mol dm^{-3}

C 0.318 mol dm^{-3}

D 0.636 mol dm^{-3}

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359. 9701_s19_qp_12 Q: 10

Ethyl ethanoate undergoes the following reaction.

$$CH_3CO_2C_2H_5 + H_2O \rightleftharpoons C_2H_5OH + CH_3CO_2H \qquad K_c = 0.27$$

Equal amounts of ethanoic acid and ethanol were mixed together and allowed to reach equilibrium.

At equilibrium, the concentrations of both ethanoic acid and ethanol were 0.42 mol dm^{-3}.

What is the concentration of ethyl ethanoate at equilibrium?

A 0.22 mol dm^{-3}

B 0.65 mol dm^{-3}

C 0.81 mol dm^{-3}

D 1.54 mol dm^{-3}

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360. 9701_s19_qp_13 Q: 9

What is the correct expression for K_c for the reaction shown?

$$I_2(aq) + 2Fe^{2+}(aq) \rightleftharpoons 2I^-(aq) + 2Fe^{3+}(aq)$$

A $\dfrac{[2I^-][2Fe^{3+}]}{[I_2][2Fe^{2+}]}$ **B** $\dfrac{[I^-]^2[Fe^{3+}]^2}{[I_2][Fe^{2+}]^2}$ **C** $\dfrac{[I_2][2Fe^{2+}]}{[2I^-][2Fe^{3+}]}$ **D** $\dfrac{[I_2][Fe^{2+}]^2}{[I^-]^2[Fe^{3+}]^2}$

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361. 9701_s19_qp_13 Q: 10

X and Y react together to form Z in a reversible reaction.

The equilibrium yield of Z is lower at higher temperature.

The equilibrium yield of Z is lower at lower pressure.

Which equation could represent this reaction?

A $X(g) + Y(g) \rightleftharpoons Z(g) \quad \Delta H = -100\,kJ\,mol^{-1}$

B $X(g) + Y(g) \rightleftharpoons Z(g) \quad \Delta H = +100\,kJ\,mol^{-1}$

C $X(s) + Y(g) \rightleftharpoons 2Z(g) \quad \Delta H = -100\,kJ\,mol^{-1}$

D $X(s) + Y(g) \rightleftharpoons 2Z(g) \quad \Delta H = +100\,kJ\,mol^{-1}$

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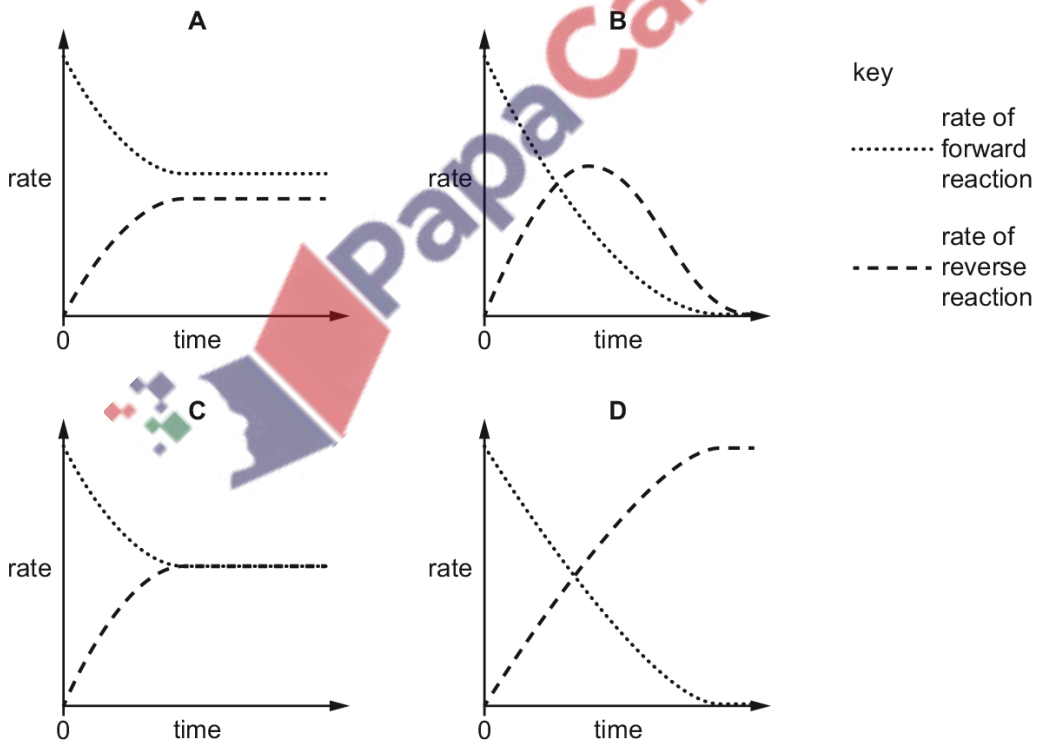
362. 9701_w19_qp_11 Q: 10

Two compounds X and Y react to produce compound Z. The reaction is reversible.

$$X + Y \rightleftharpoons Z$$

When X and Y are mixed together in a closed system a dynamic equilibrium is gradually established.

Which graph could represent the change in the rates of the forward and reverse reactions over time?



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363. 9701_w19_qp_11 Q: 11

The reaction between sulfur dioxide and oxygen is reversible.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad K_c = 280\,mol^{-1}\,dm^3 \text{ at } 1000\,K$$

In an equilibrium mixture at 1000 K the sulfur dioxide concentration is 0.200 mol dm^{-3} and the oxygen concentration is 0.100 mol dm^{-3}.

What is the sulfur trioxide concentration?

A 1.058 mol dm^{-3}

B 1.120 mol dm^{-3}

C 2.366 mol dm^{-3}

D 5.600 mol dm^{-3}

---

364. 9701_w19_qp_12 Q: 10

The decomposition of $SO_3(g)$ is a dynamic equilibrium.

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

What happens when the pressure of the system is increased?

A The rate of reaction will decrease and the position of the equilibrium will move to the left.

B The rate of reaction will decrease and the position of the equilibrium will move to the right.

C The rate of reaction will increase and the position of the equilibrium will move to the left.

D The rate of reaction will increase and the position of the equilibrium will move to the right.

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365. 9701_m18_qp_12 Q: 13

Which oxide is insoluble in aqueous sodium hydroxide?

A MgO **B** Al_2O_3 **C** P_4O_{10} **D** SO_2

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366. 9701_m18_qp_12 Q: 14

X, Y and Z are three elements in the third period.

- X reacts with chlorine to give a liquid product.
- Y reacts with chlorine to give a solid product that dissolves in water to give a solution of pH 7.
- Z reacts with chlorine to give a solid product that dissolves in water to give a solution of pH 6.

Which elements are good conductors of electricity?

A X and Y **B** Y and Z **C** Y only **D** Z only

---

367. 9701_s18_qp_12 Q: 5

The gases X and Y react to form Z.

$$X(g) + Y(g) \rightleftharpoons Z(g)$$

An equilibrium mixture of these three gases is compressed at constant temperature.

What will be the changes in the mole fraction of Z and in K_p?

	mole fraction of Z	K_p
A	increase	increase
B	increase	no change
C	no change	increase
D	no change	no change

---

368. 9701_s18_qp_12 Q: 10

In a particular reversible reaction the yield of product is increased

- if the temperature is increased;
- if the pressure is decreased.

Which equation could describe this reversible reaction?

A $CH_4(g) + H_2O(g) \rightleftharpoons 3H_2(g) + CO(g)$ $\Delta H = +206\,kJ\,mol^{-1}$

B $4NH_3(g) + 3O_2(g) \rightleftharpoons 2N_2(g) + 6H_2O(g)$ $\Delta H = -227\,kJ\,mol^{-1}$

C $2NO_2(g) \rightleftharpoons N_2O_4(g)$ $\Delta H = -58\,kJ\,mol^{-1}$

D $3O_2(g) \rightleftharpoons 2O_3(g)$ $\Delta H = +143\,kJ\,mol^{-1}$

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369. 9701_s18_qp_13 Q: 9

Hydrogen is produced industrially from methane as shown in the equation.

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g) \qquad \Delta H^\ominus = +205\,kJ\,mol^{-1}$$

Which conditions would most favour the formation of hydrogen?

	pressure	temperature
A	high	high
B	high	low
C	low	high
D	low	low

---

370. 9701_s18_qp_13 Q: 10

The chemical equilibrium shown is formed when ammonia is produced in the Haber process.

$$N_2 + 3H_2 \rightleftharpoons 2NH_3$$

The following concentrations are found to be present at equilibrium under certain conditions.

N_2	H_2	NH_3
$0.200\,mol\,dm^{-3}$	$0.300\,mol\,dm^{-3}$	$0.600\,mol\,dm^{-3}$

What is the numerical value of K_c under these conditions?

A 0.0150 **B** 6.0 **C** 10.0 **D** 66.7

---

371. 9701_s18_qp_13 Q: 17

Silver chloride and silver iodide form equilibria when added to water.

$$AgCl(s) \rightleftharpoons Ag^+(aq) + Cl^-(aq) \qquad K_c = K_1$$

$$AgI(s) \rightleftharpoons Ag^+(aq) + I^-(aq) \qquad K_c = K_2$$

Each equilibrium position lies well to the **left**.

Silver iodide will not dissolve in aqueous ammonia. Silver chloride will dissolve in aqueous ammonia. Another equilibrium is formed.

$$Ag^+(aq) + 2NH_3(aq) \rightleftharpoons Ag(NH_3)_2^+(aq) \qquad K_c = K_3$$

The position of this equilibrium lies to the **right**.

What is the order of magnitude for these three equilibrium constants?

A $K_1 > K_2 > K_3$

B $K_2 > K_1 > K_3$

C $K_3 > K_1 > K_2$

D $K_3 > K_2 > K_1$

---

372. 9701_s18_qp_13 Q: 18

Elements and their compounds are important as catalysts.

In which process is a compound used, rather than an element?

A catalytic converters

B Contact process

C Haber process

D hydrogenation of alkenes

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373. 9701_w18_qp_11 Q: 9

In this question you should assume that all gases behave ideally.

Hydrogen and iodine react reversibly in the following reaction. The system reaches dynamic equilibrium.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g) \qquad \Delta H = -9.5\,kJ\,mol^{-1}$$

Which statement **must** be true for the K_p of this equilibrium to be constant?

A The partial pressures of H_2, I_2 and HI are equal.

B The external pressure is constant.

C The forward and reverse reactions have stopped.

D The temperature is constant.

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374. 9701_w18_qp_11 Q: 10

0.200 mol of sulfur dioxide and 0.200 mol of oxygen are placed in a 1.00 dm^3 sealed container. The gases are allowed to react until equilibrium is reached.

$$2SO_2 + O_2 \rightleftharpoons 2SO_3$$

At equilibrium there is 0.100 mol of SO_3 in the container.

What is the value of K_c?

A 0.150 $mol\,dm^{-3}$

B 0.800 $mol\,dm^{-3}$

C 1.25 $mol^{-1}\,dm^3$

D 6.67 $mol^{-1}\,dm^3$

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375. 9701_w18_qp_12 Q: 9

In this question, all pressures are measured in atm.

The equation represents the equilibrium between three gaseous substances X, Y and Z.

$$X + 3Y \rightleftharpoons 2Z$$

At temperature T_1, the numerical value of K_p, the equilibrium constant, is 2.

At a higher temperature T_2, the partial pressures at equilibrium are as shown.

X	Y	Z
2	3	5

Which row is correct?

	the numerical value of K_p at T_2	the forward reaction is
A	54/25	endothermic
B	54/25	exothermic
C	25/54	endothermic
D	25/54	exothermic

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376. 9701_m17_qp_12 Q: 3

Two moles of compound P were placed in a sealed container. The container was heated and P was partially decomposed to produce Q and R only. A dynamic equilibrium between P, Q and R was established.

At equilibrium x moles of R were present and the total number of moles present was $\left(2+\frac{x}{2}\right)$.

What is the equation for this reversible reaction?

A $P \rightleftharpoons 2Q + R$

B $2P \rightleftharpoons 2Q + R$

C $2P \rightleftharpoons Q + R$

D $2P \rightleftharpoons Q + 2R$

---

377. 9701_m17_qp_12 Q: 11

Ammonia is manufactured from nitrogen and hydrogen using the Haber process.

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

What is the expression for K_c for this equilibrium?

A $\dfrac{2[NH_3(g)]}{[N_2(g)] + 3[H_2(g)]}$

B $\dfrac{2[NH_3(g)]}{[N_2(g)] \times 3[H_2(g)]}$

C $\dfrac{[NH_3(g)]^2}{[N_2(g)] + [H_2(g)]^3}$

D $\dfrac{[NH_3(g)]^2}{[N_2(g)] \times [H_2(g)]^3}$

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378. 9701_s17_qp_11 Q: 10

Methanol can be produced from hydrogen and carbon monoxide.

$$2H_2(g) + CO(g) \rightleftharpoons CH_3OH(g)$$

What is the expression for K_p for this reaction?

A $K_p = \dfrac{(2p_{H_2})^2 \times p_{CO}}{p_{CH_3OH}}$

B $K_p = \dfrac{(p_{H_2})^2 \times p_{CO}}{p_{CH_3OH}}$

C $K_p = \dfrac{p_{CH_3OH}}{(p_{H_2})^2 \times p_{CO}}$

D $K_p = \dfrac{p_{CH_3OH}}{p_{CO} \times (2p_{H_2})^2}$

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379. 9701_s17_qp_12 Q: 9

Hydrogen and carbon dioxide gases are mixed at 800 K. A reversible reaction takes place.

$$H_2(g) + CO_2(g) \rightleftharpoons H_2O(g) + CO(g)$$

At equilibrium, the partial pressures of H_2 and CO_2 are both 10.0 kPa. K_p is 0.288 at 800 K.

What is the partial pressure of CO in the equilibrium mixture?

A 5.37 kPa **B** 18.6 kPa **C** 28.8 kPa **D** 347 kPa

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380. 9701_s17_qp_12 Q: 10

A reaction involved in the Contact process is shown.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H^\ominus = -197\,kJ\,mol^{-1}$$

The reaction is investigated at 200 kPa and 700 K and the value of the equilibrium constant, K_p, is found to be Y. The reaction is then investigated at 1000 kPa and 700 K and the value of K_p is found to be Z.

Which statement comparing Y and Z is correct?

A Y and Z are the same.

B Y is greater than Z.

C Z is 2.2 times greater than Y.

D Z is 5.0 times greater than Y.

---

381. 9701_s17_qp_13 Q: 9

Ammonia is produced by the Haber process.

$$N_2 + 3H_2 \rightleftharpoons 2NH_3 \qquad \Delta H^\ominus = -92\,kJ\,mol^{-1}$$

A fault in the temperature control during the process resulted in the temperature changing to 600 °C for two hours.

What effect did this have on the ammonia production during this time?

A Ammonia was formed faster. The equilibrium yield decreased.

B Ammonia was formed faster. The equilibrium yield increased.

C Ammonia was formed slower. The equilibrium yield decreased.

D Ammonia was formed slower. The equilibrium yield increased.

---

382. 9701_s17_qp_13 Q: 10

For the reaction shown, an equilibrium is established at a temperature of 700 K.

The equilibrium constant, K_p, for the reaction is 9.80 kPa. The partial pressure of N_2O_4 at equilibrium is 80.0 kPa.

$$N_2O_4(g) \rightleftharpoons 2NO_2(g)$$

What is the partial pressure of NO_2 at equilibrium?

A 8.16 kPa **B** 28.0 kPa **C** 66.6 kPa **D** 784 kPa

---

383. 9701_w17_qp_11 Q: 9

Hydrogen iodide dissociates into hydrogen and iodine.

$$2HI(g) \rightleftharpoons H_2(g) + I_2(g)$$

In an experiment, b mol of hydrogen iodide were put into a sealed vessel at pressure p. At equilibrium, x mol of the hydrogen iodide had dissociated.

Which expression for K_p is correct?

A $\dfrac{x^2}{(b-x)^2}$ **B** $\dfrac{x^2p^2}{(b-x)^2}$ **C** $\dfrac{x^2p^2}{4b(b-x)}$ **D** $\dfrac{x^2}{4(b-x)^2}$

---

384. 9701_w17_qp_12 Q: 9

Nitrogen dioxide, NO_2, is a brown gas.

Dinitrogen tetroxide, N_2O_4, is a colourless gas.

An equilibrium is established between NO_2 and N_2O_4 in a closed vessel.

$$\underset{\text{brown}}{2NO_2(g)} \rightleftharpoons \underset{\text{colourless}}{N_2O_4(g)} \qquad \Delta H = -57\ \text{kJ mol}^{-1}$$

Which row describes the effects of changing conditions on the colour of an equilibrium mixture of NO_2 and N_2O_4?

	increasing the pressure	increasing the temperature
A	colour becomes darker	colour becomes darker
B	colour becomes darker	colour becomes lighter
C	colour becomes lighter	colour becomes darker
D	colour becomes lighter	colour becomes lighter

---

385. 9701_m16_qp_12 Q: 11

In an experiment, 2.00 mol of hydrogen and 3.00 mol of iodine were heated together in a sealed container and allowed to reach equilibrium at a fixed temperature. The container had a fixed volume of 1.00 dm^3. At equilibrium, there were 2.40 mol of iodine present in the mixture.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$

What is the value of the equilibrium constant, K_c?

A 0.107 **B** 0.357 **C** 0.429 **D** 2.33

---

386. 9701_s16_qp_11 Q: 9

An aqueous solution was prepared containing a mixture of 1.0 mol of $AgNO_3$ and 1.0 mol of $FeSO_4$ in 1.00 dm^3 of water. When equilibrium was established, there was 0.44 mol of $Ag^+(aq)$ in the mixture.

$$Ag^+(aq) + Fe^{2+}(aq) \rightleftharpoons Ag(s) + Fe^{3+}(aq)$$

What is the numerical value of K_c?

A 0.62 **B** 1.40 **C** 1.62 **D** 2.89

---

387. 9701_s16_qp_11 Q: 10

The equation for the reaction between carbon monoxide and hydrogen is shown.

$$CO(g) + 3H_2(g) \rightleftharpoons CH_4(g) + H_2O(g)$$

What are the units of K_p for this reaction?

A kPa **B** kPa^{-1} **C** kPa^2 **D** kPa^{-2}

---

388. 9701_s16_qp_12 Q: 10

When solid ammonium chloride dissociates at a certain temperature in a 0.500 dm^3 container, ammonia and hydrogen chloride are formed.

$$NH_4Cl(s) \rightleftharpoons NH_3(g) + HCl(g)$$

The initial amount of ammonium chloride was 1.00 mol, and when the system had reached equilibrium there was 0.300 mol of ammonium chloride.

What is the numerical value of K_c for this reaction under these conditions?

A 0.490 **B** 1.63 **C** 1.96 **D** 3.27

---

389. 9701_s16_qp_13 Q: 9

The equilibrium constant, K_c, for the reaction shown is 2 mol^{-2} dm^6, at 600 K.

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

What is the concentration of NH_3 at equilibrium, at 600 K, when the equilibrium concentrations of N_2 and H_2 are both 2 mol dm^{-3}?

A $\sqrt{8}$ mol dm^{-3} **B** $\sqrt{16}$ mol dm^{-3} **C** $\sqrt{32}$ mol dm^{-3} **D** 32 mol dm^{-3}

---

390. 9701_s16_qp_13 Q: 11

Catalysts are an important feature of many industrial processes and biochemical reactions.

Which row correctly describes the effect of a catalyst on a reversible chemical reaction?

	position of equilibrium	effect on value of ΔH
A	moved to right	decreased
B	unaffected	decreased
C	unaffected	increased
D	unaffected	unaffected

---

391. 9701_w16_qp_11 Q: 10

The table shows the partial pressures in an equilibrium mixture formed by the Haber process.

substance	partial pressure / kPa
nitrogen	7000
hydrogen	8000
ammonia	4000

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

What is the numerical value of the equilibrium constant, K_p, for this reaction?

A 4.46×10^{-9}

B 4.76×10^{-5}

C 7.14×10^{-5}

D 2.24×10^{8}

---

392. 9701_w16_qp_12 Q: 10

Nitrogen reacts with hydrogen to produce ammonia.

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

A mixture of 2.00 mol of nitrogen, 6.00 mol of hydrogen and 2.40 mol of ammonia is allowed to reach equilibrium in a sealed vessel of volume 1 dm^3. It was found that 2.32 mol of nitrogen were present in the equilibrium mixture.

What is the value of K_c?

A $\dfrac{(1.76)^2}{(2.32)(6.96)^3}$

B $\dfrac{(1.76)^2}{(2.32)(6.32)^3}$

C $\dfrac{(2.08)^2}{(2.32)(6.32)^3}$

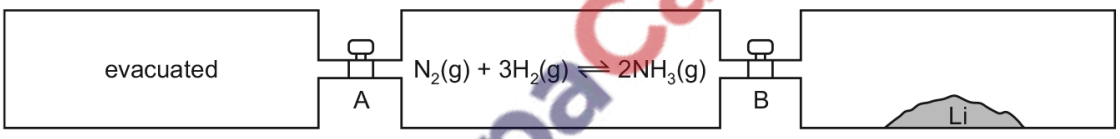
D $\dfrac{(2.40)^2}{(2.32)(6.00)^3}$

---

393. 9701_w16_qp_12 Q: 11

Lithium reacts with nitrogen at room temperature to form solid Li_3N.

Three vessels of equal volume are connected by taps, A and B, as shown.



At the start, A and B are closed, the left-hand vessel is evacuated, the middle vessel has the indicated reaction at equilibrium and the right-hand vessel contains lithium only.

Which action would allow the equilibrium mixture to contain the **most** ammonia?

A Keep both A and B closed.

B Open both A and B.

C Open A only.

D Open B only.

---

394. 9701_s15_qp_11 Q: 6

One mole of phosphorus(V) chloride, PCl_5, is heated to 600 K in a sealed flask of volume 1 dm^3. Equilibrium is established and measurements are taken.

$$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$$

The experiment is repeated with one mole of phosphorus(V) chloride heated to 600 K in a sealed flask of volume 2 dm^3.

How will the measurements vary?

A The equilibrium concentrations of $PCl_3(g)$ and $Cl_2(g)$ are higher in the second experiment.

B The equilibrium concentration of $PCl_5(g)$ is lower in the second experiment.

C The equilibrium concentrations of all three gases are the same in both experiments.

D The value of the equilibrium constant is higher in the second experiment.

---

395. 9701_s15_qp_11 Q: 9

One molecule of haemoglobin, Hb, can bind with four molecules of oxygen according to the following equation.

$$Hb(aq) + 4O_2(aq) \rightleftharpoons Hb(O_2)_4(aq)$$

When the equilibrium concentration of O_2 is 7.6×10^{-6} mol dm^{-3}, the equilibrium concentrations of Hb and $Hb(O_2)_4$ are equal.

What is the value of K_c for this equilibrium?

A 3.0×10^{20} **B** 1.3×10^{5} **C** 7.6×10^{-6} **D** 3.3×10^{-21}

---

396. 9701_s15_qp_12 Q: 8

Nitrogen dioxide, NO_2, exists in equilibrium with dinitrogen tetroxide, N_2O_4.

$$2NO_2(g) \rightleftharpoons N_2O_4(g) \qquad \Delta H = -57\ kJ\ mol^{-1}$$

Which conditions give the greatest percentage of $N_2O_4(g)$ at equilibrium?

	pressure	temperature
A	high	high
B	high	low
C	low	high
D	low	low

---

397. 9701_s15_qp_12 Q: 9

When a sample of HI is warmed to a particular temperature the equilibrium below is established.

$$2HI(g) \rightleftharpoons H_2(g) + I_2(g)$$

At this temperature, it is found that the partial pressure of HI(g) is 28 times the partial pressure of $H_2(g)$.

What is the value of K_p at this temperature?

A 1.28×10^{-3} **B** 0.035 **C** 28 **D** 784

---

398. 9701_w15_qp_11 Q: 2

Which set of conditions gives the highest yield of ammonia at equilibrium?

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H^{\ominus} = -92\,kJ\,mol^{-1}$$

	catalyst	pressure	temperature
A	absent	high	low
B	absent	low	high
C	present	high	high
D	present	low	low

---

399. 9701_w15_qp_11 Q: 10

A mixture of nitrogen and hydrogen gases, at a temperature of 500 K, was put into an evacuated vessel of volume 6.0 dm^3. The vessel was then sealed.

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

The mixture was allowed to reach equilibrium. It was found that 7.2 mol of N_2 and 12.0 mol of H_2 were present in the equilibrium mixture. The value of the equilibrium constant, K_c, for this equilibrium is 6.0×10^{-2} at 500 K.

What is the concentration of ammonia present in the equilibrium mixture at 500 K?

A 0.58 mol dm^{-3}

B 0.76 mol dm^{-3}

C 3.5 mol dm^{-3}

D 27 mol dm^{-3}

---

400. 9701_w15_qp_12 Q: 8

Hydrogen can be obtained by reacting methane with steam.

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g) \qquad \Delta H^{\ominus} = +210\,kJ\,mol^{-1}$$

Which conditions of pressure and temperature will give the greatest equilibrium yield of hydrogen?

	pressure	temperature
A	high	high
B	high	low
C	low	high
D	low	low

---

401. 9701_w15_qp_12 Q: 9

Nitrogen monoxide reacts with oxygen in a reversible reaction according to the equation shown below.

$$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$$

The partial pressures of each of the components in an equilibrium mixture are shown in the table.

partial pressure NO / kPa	partial pressure O_2 / kPa	partial pressure NO_2 / kPa
10	30	20

What is the numerical value of the equilibrium constant, K_p, for this equilibrium?

A 6.67×10^{-2} **B** 1.33×10^{-1} **C** 7.50 **D** 15.0

7.2 Brønsted–Lowry theory of acids and bases

402. 9701_m22_qp_12 Q: 13

Diethylzinc, $(C_2H_5)_2Zn$, is added to NaOH(aq). Two reactions occur.

reaction 1 $(C_2H_5)_2Zn + H_2O \rightarrow ZnO + 2C_2H_6$

reaction 2 $H_2O + ZnO + 2OH^- \rightarrow Zn(OH)_4^{2-}$

In these reactions, which compounds act as Brønsted–Lowry acids?

	reaction 1	reaction 2
A	$(C_2H_5)_2Zn$	H_2O
B	H_2O	H_2O
C	H_2O	ZnO
D	the reaction is not acid / base	ZnO

---

403. 9701_m21_qp_12 Q: 9

In which reaction is water behaving as a Brønsted–Lowry base?

A $H_2O + Na \rightarrow NaOH + \frac{1}{2}H_2$

B $H_2O + H_3PO_4 \rightarrow H_3O^+ + H_2PO_4^-$

C $H_2O + CaO \rightarrow Ca(OH)_2$

D $NH_3 + [Cu(H_2O)_6]^{2+} \rightarrow NH_4^+ + [Cu(H_2O)_5(OH)]^+$

---

404. 9701_w21_qp_11 Q: 7

In order to determine the enthalpy of neutralisation of a strong acid and a strong alkali, 25.0 cm^3 of 2.00 mol dm^{-3} sodium hydroxide is added to 25.0 cm^3 of 2.00 mol dm^{-3} hydrochloric acid. The increase in temperature is 12 °C.

In a second experiment, the same method is used, but 50.0 cm^3 of 2.00 mol dm^{-3} sodium hydroxide is added to 50.0 cm^3 of 2.00 mol dm^{-3} hydrochloric acid.

What is the increase in temperature in the second experiment?

A 6 °C **B** 12 °C **C** 24 °C **D** 48 °C

---

405. 9701_s20_qp_13 Q: 6

Which solution has the lowest pH value?

A 0.01 mol dm^{-3} butanoic acid

B 0.01 mol dm^{-3} ethanoic acid

C 0.01 mol dm^{-3} hydrochloric acid

D 0.01 mol dm^{-3} sulfuric acid

---

406. 9701_m18_qp_12 Q: 15

A solution contains both $Mg^{2+}(aq)$ and $Sr^{2+}(aq)$ at the same concentration.

The solution is divided into two equal portions. Aqueous sodium hydroxide is added dropwise to one portion. Dilute sulfuric acid is added dropwise to the other portion.

Which row is correct?

	precipitate seen first when NaOH(aq) is added	precipitate seen first when $H_2SO_4(aq)$ is added
A	magnesium hydroxide	magnesium sulfate
B	magnesium hydroxide	strontium sulfate
C	strontium hydroxide	magnesium sulfate
D	strontium hydroxide	strontium sulfate

---

407. 9701_s18_qp_11 Q: 15

In which reaction does ammonia behave as a Brønsted-Lowry base?

A $NH_3 + CH_3CH_2Br \rightarrow CH_3CH_2NH_2 + HBr$

B $NH_3 + H_2O + CO_2 \rightarrow (NH_4)HCO_3$

C $2NH_3 + 2Na \rightarrow 2NaNH_2 + H_2$

D $4NH_3 + 3O_2 \rightarrow 2N_2 + 6H_2O$

---

408. 9701_s16_qp_13 Q: 10

Sulfur dioxide is used as a preservative in wine making.

The following equations describe the reactions that occur when sulfur dioxide dissolves in water.

$$H_2O + SO_2 \rightleftharpoons HSO_3^- + H^+$$

$$HSO_3^- + H^+ \rightleftharpoons SO_3^{2-} + 2H^+$$

Which statement about **these two reactions** is correct?

A HSO_3^- acts as a base.

B SO_2 acts as an oxidising agent.

C SO_3^{2-} acts as an acid.

D SO_3^{2-} acts as a reducing agent.

---

409. 9701_s15_qp_11 Q: 8

In which reaction is the underlined substance acting as a base?

A $HNO_3 + \underline{H_2SO_4} \rightarrow H_2NO_3^+ + HSO_4^-$

B $HSiO_3^- + \underline{HCN} \rightarrow CN^- + H_2O + SiO_2$

C $HNO_2 + \underline{HCO_3^-} \rightarrow H_2O + CO_2 + NO_2^-$

D $C_6H_5O^- + \underline{CH_2ClCO_2H} \rightarrow C_6H_5OH + CH_2ClCO_2^-$
