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2002

XVIII

1583

Time allowed
28 Minutes

Score /23

Percentage %

CHEMISTRY

AQA
AS & A LEVEL

Topic Questions

3.1 Physical chemistry

1. When one mole of ammonia is heated to a given temperature, 50 per cent of the compound dissociates and the following equilibrium is established.

$$NH_3(g) \rightleftharpoons \tfrac{1}{2} N_2(g) + \tfrac{3}{2} H_2(g)$$

What is the total number of moles of gas present in this mixture?

A 1.5

B 2.0

C 2.5

D 3.0

(Total 1 mark)

2. A sample of chlorine gas was sealed in a tube, heated and an equilibrium was established.

$$Cl_2(g) \rightleftharpoons 2Cl(g)$$

Which one of the following is **not** true?

A The concentration of chlorine atoms remains the same when a catalyst is added to the tube.

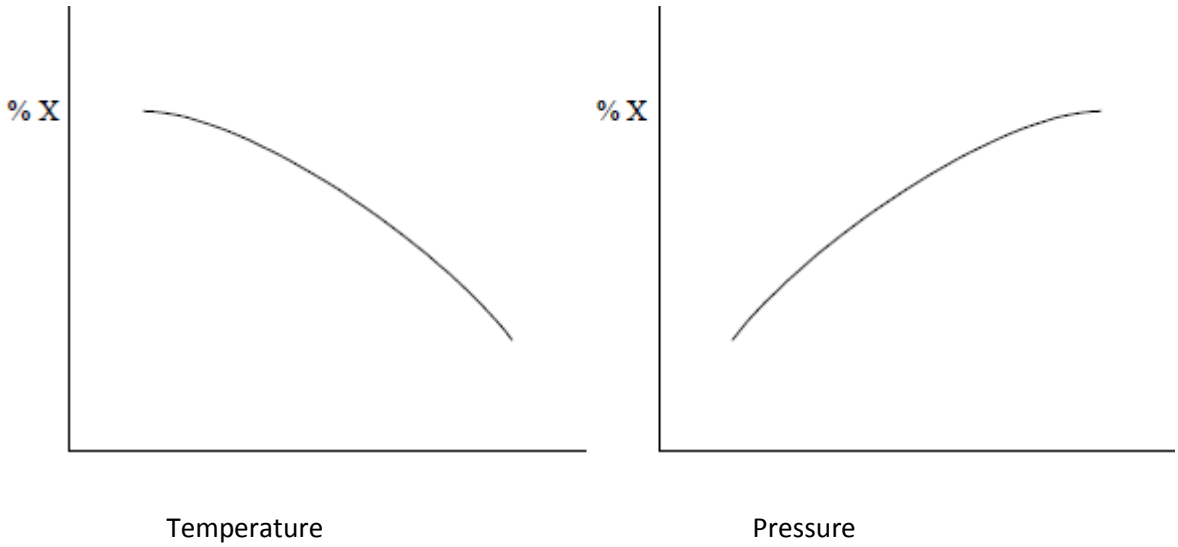
B Increase in temperature causes an increase in the concentration of chlorine atoms.

C Increase in pressure causes an increase in the concentration of chlorine atoms relative to chlorine molecules.

D Addition of more chlorine gas to the tube causes an increase in the concentration of chlorine atoms.

(Total 1 mark)

3. A compound **X** is formed during a gas phase reaction. The graphs below show how the percentage of a compound **X** present at equilibrium varies with temperature and pressure.



Which one of the following statements concerning the formation of **X** is correct?

A The reaction is exothermic and involves a decrease in the number of moles of gas.

B The reaction is exothermic and involves no change in the number of moles of gas.

C The reaction is exothermic and involves an increase in the number of moles of gas.

D The reaction is endothermic and involves a decrease in the number of moles of gas.

(Total 1 mark)

4 A weak acid HA dissociates in aqueous solution as shown below

$$HA(aq) \rightleftharpoons H^+(aq) + A^-(aq) \qquad \Delta H = +20 \text{ kJ mol}^{-1}$$

Which one of the following changes will result in a decrease in the pH of an aqueous solution of the acid?

A addition of a little aqueous sodium hydroxide solution

B raising the temperature of the solution

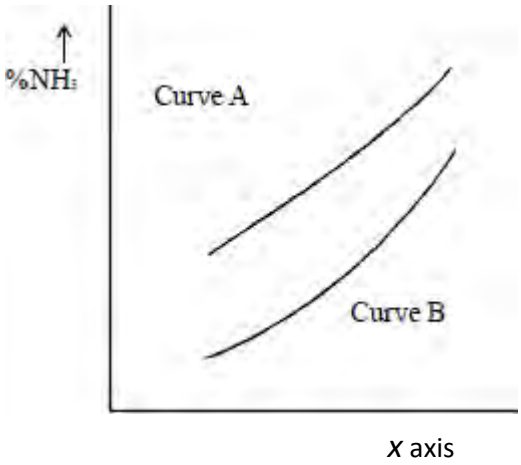
C dissolving a little of the sodium salt, NaA, in the solution

D adding a platinum catalyst to the solution

(Total 1 mark)

5 The graph shows the equilibrium percentage of ammonia present during the formation of ammonia by the Haber process:

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



Which one of the following are correct labels for the graph?

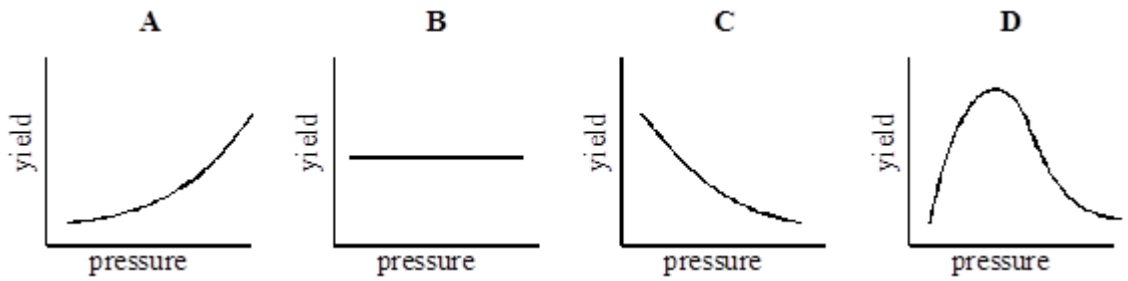
	x axis	*Curve A*	*Curve B*
A	temperature	high pressure	low pressure
B	temperature	low pressure	high pressure
C	pressure	high temperature	low temperature
D	pressure	low temperature	high temperature

(Total 1 mark)

6 Phosphorus(V) chloride decomposes at high temperatures into phosphorus(III) chloride and chlorine according to the equation.

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

Which one of the graphs best represents the variation with pressure of the yield of chlorine at equilibrium?



(Total 1 mark)

7 The equilibrium constant, K_c, for a reaction which leads to ozone (O_3) formation is

$$K_c = \frac{[N_2][O_3]^2}{[NO]^2[O_2]^2}$$

More ozone is formed as the temperature rises. Which one of the following is true at equilibrium?

A When ozone molecules collide with nitrogen they may form nitrogen monoxide.

B The enthalpy change for the reaction has a negative sign.

C Less ozone is formed at high pressure.

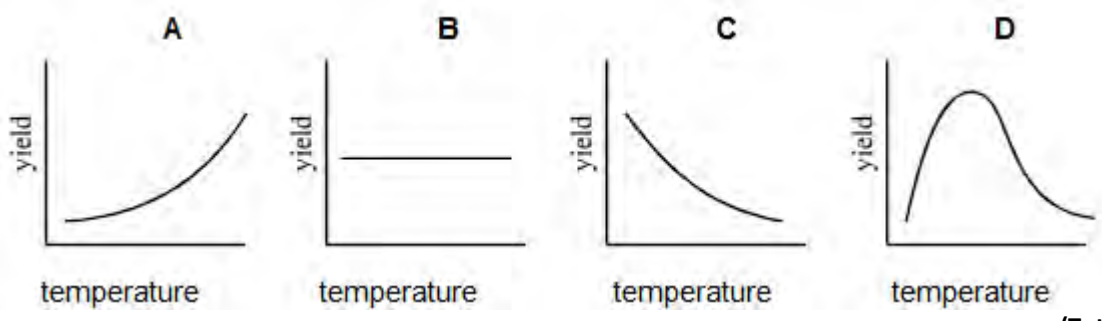
D At a fixed temperature, the magnitude of K_c increases as the concentration of NO decreases.

(Total 1 mark)

8 Normal water and heavy water react together to form isotopicaily mixed water according to the equation

$$H_2O(l) + D_2O(l) \rightleftharpoons 2HDO(l)$$

The standard enthalpy of formation of $H_2O(l)$ is −286 kJ mol^{-1}, that of $D_2O(l)$ is −294 kJ mol^{-1}, and that of HDO(l) is −290 kJ mol^{-1}. Which one of the following best represents the variation with temperature of the yield of HDO at equilibrium?



(Total 1 mark)

9 Methanol is synthesised from carbon monoxide and hydrogen according to the equation below.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \qquad \Delta H^{\ominus} = -91 \text{ kJ mol}^{-1}$$

Which one of the following changes would **not** affect the value of the equilibrium constant and would **not** increase the yield of methanol?

A increase in temperature

B decrease in temperature

C increase in pressure

D decrease in pressure

(Total 1 mark)

10 When one mole of ammonia is heated to a high temperature, 50% dissociates according to the following equilibrium.

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

What is the total number of moles of gas present in the equilibrium mixture?

A 1.5

B 2.0

C 2.5

D 3.0

(Total 1 mark)

11 The following information concerns the equilibrium gas-phase synthesis of methanol.

$CO(g) + 2H_2(g) \rightleftharpoons CH3OH(g)$

At equilibrium, when the temperature is 68 °C, the total pressure is 1.70 MPa.
The number of moles of CO, H_2 and CH_3OH present are 0.160, 0.320 and 0.180, respectively.

Thermodynamic data are given below.

Substance	$\Delta H_f^{\ominus}$ / kJ mol^{-1}	$S^{\ominus}$ / J K^{-1} mol^{-1}
CO(g)	−110	198
H_2(g)	0	131
CH_3OH(g)	−201	240

Which one of the following statements applies to this equilibrium?

A The value of K_p increases if the temperature is raised.

B The value of K_p increases if the pressure is raised.

C The yield of methanol decreases if the temperature is lowered.

D The yield of methanol decreases if the pressure is lowered.

(Total 1 mark)

12 The ester methyl ethanoate is hydrolysed as shown in the following equation.

$$CH_3COOCH_3(l) + H_2O(l) \rightleftharpoons CH_3COOH(l) + CH_3OH(l) \quad \Delta H^{\ominus} = +3 \text{ kJ mol}^{-1}$$

A 3 mol sample of methyl ethanoate was mixed with 3 mol of water and left to reach equilibrium at 298 K. The equilibrium yield of ethanoic acid was 2 mol. The value of K_c for this reaction at 298 K is

A $\frac{2}{3}$

B $\frac{4}{9}$

C 2

D 4

(Total 1 mark)

13 The ester methyl ethanoate is hydrolysed as shown in the following equation.

$$CH_3COOCH_3(l) + H_2O(l) \rightleftharpoons CH_3COOH(l) + CH_3OH(l) \quad \Delta H^{\ominus} = +3 \text{ kJ mol}^{-1}$$

The equilibrium yield of ethanoic acid could be increased by

A lowering the temperature.

B adding a catalyst.

C adding more water to the reaction mixture.

D adding more methanol to the reaction mixture.

(Total 1 mark)

14 Use the information below to answer this question.

A saturated solution of magnesium hydroxide, $Mg(OH)_2$, contains 0.1166 g of $Mg(OH)_2$ in 10.00 dm^3 of solution. In this solution the magnesium hydroxide is fully dissociated into ions.

The equilibrium constant expression for the dissolving of magnesium hydroxide is $K = [Mg^{2+}][OH^-]^2$. In a saturated solution of $Mg(OH)_2$ at a different temperature, the concentration of hydroxide ions is 1.0×10^{-3} mol dm^{-3}.

Which one of the following has the correct value and units for *K* under these conditions?

A 1.0×10^{-6} mol^2 dm^{-6}

B 5.0×10^{-7} mol^2 dm^{-6}

C 1.0×10^{-9} mol^3 dm^{-9}

D 5.0×10^{-10} mol^3 dm^{-9}

(Total 1 mark)

15 The data below refer to the industrial production of nitric acid from ammonia.

Reaction 1 $4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g)$ $\Delta H^{\ominus} = -909$ kJ mol^{-1}

Reaction 2 $2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$ $\Delta H^{\ominus} = -115$ kJ mol^{-1}

Reaction 3 $3NO_2(g) + H_2O(l) \rightleftharpoons 2HNO_3(aq) + NO(g)$ $\Delta H^{\ominus} = -117$ kJ mol^{-1}

The equilibrium yield in **all three** reactions is increased when

A the pressure is increased.

B the pressure is decreased.

C the temperature is increased.

D the temperature is decreased.

(Total 1 mark)

16 The data below refer to the industrial production of nitric acid from ammonia.

Reaction 1 $4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g)$ $\Delta H^{\ominus} = -909\ kJ\ mol^{-1}$

Reaction 2 $2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$ $\Delta H^{\ominus} = -115\ kJ\ mol^{-1}$

Reaction 3 $3NO_2(g) + H_2O(l) \rightleftharpoons 2HNO_3(aq) + NO(g)$ $\Delta H^{\ominus} = -117\ kJ\ mol^{-1}$

Possible units for the equilibrium constant, K_c, for *reaction 2* are

A $mol^{-2}\ m^6$

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

C no units

D $mol\ dm^{-3}$

(Total 1 mark)

17 Ethanoic acid reacts with ethanol in a reversible reaction represented by the equation below. In an experiment 3.0 mol of ethanoic acid were mixed with 1.0 mol of ethanol and when the reaction had reached equilibrium 0.9 mol of water had been formed.

$$CH_3COOH(l) + C_2H_5OH(l) \rightleftharpoons CH_3COOC_2H_5(l) + H_2O(l)$$

The percentage of ethanoic acid converted into the ester $CH_3COOC_2H_5$ in this reaction is

A 22.5%

B 30%

C 43%

C 90%

(Total 1 mark)

18 Ethanoic acid reacts with ethanol in a reversible reaction represented by the equation below. In an experiment 3.0 mol of ethanoic acid were mixed with 1.0 mol of ethanol and when the reaction had reached equilibrium 0.9 mol of water had been formed.

$$CH_3COOH(l) + C_2H_5OH(l) \rightleftharpoons CH_3COOC_2H_5(l) + H_2O(l)$$

The equilibrium constant for the reaction under these conditions is

A 0.20

B 0.23

C 3.9

C 4.3

(Total 1 mark)

19 Refer to the following reaction

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g) \quad \Delta H^{\ominus} = -11 \text{ kJ mol}^{-1}, \quad \Delta S^{\ominus} = +20 \text{ J K}^{-1} \text{ mol}^{-1}$$

Which one of the following statements is correct?

A This is a redox reaction.

B The reaction is **not** feasible below 298 K

C At equilibrium, the yield of hydrogen iodide is changed by increasing the pressure.

D At equilibrium, the yield of hydrogen iodide increases as the temperature is increased.

(Total 1 mark)

20 Use the information about the following solutions to answer the question below.

Solution F: This is a mixture of 1 mol of propanoic acid, 1 mol of methanol and 2 mol of water.

Solution G: This was originally the same mixture as solution **F** but it has been left to reach equilibrium.

Solution **G** was found to contain 0.5 mol of propanoic acid. Which one of the following is the value of the equilibrium constant (K_c) for the following equilibrium?

$$\text{propanoic acid + methanol} \rightleftharpoons \text{methyl propanoate + water}$$

A 0.2

B 1

C 5

D 10

(Total 1 mark)

21 Use the information about the following solutions to answer the question below.

Solution F: This is a mixture of 1 mol of propanoic acid, 1 mol of methanol and 2 mol of water.

Solution G: This was originally the same mixture as solution **F** but it has been left to reach equilibrium.

Compared to the pH of solution **F**, the pH of solution **G** will be

A considerably lower.

B slightly lower.

C slightly higher.

D exactly the same.

(Total 1 mark)

22 The standard enthalpy of formation, ΔH_f for $O_3(g)$ is + 142 kJ mol^{-1}. In which one of the following would both the changes shown increase the amount of O_2 gas in an equilibrium mixture containing only $O_2(g)$ and $O_3(g)$?

A increasing the temperature and increasing the pressure

B increasing the temperature and decreasing the pressure

C decreasing the temperature and increasing the pressure

D decreasing the temperature and decreasing the pressure

(Total 1 mark)

23 When one mole of ammonia is heated to a given temperature, 50% of the compound dissociates and the following equilibrium is established.

$$NH_3(g) \rightleftharpoons \frac{1}{2}N_2(g) + \frac{3}{2}H_2(g)$$

What is the total number of moles of gas present in this equilibrium mixture?

A 1.5

B 2.0

C 2.5

D 3.0

(Total 1 mark)