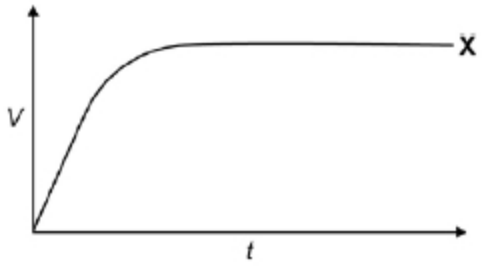
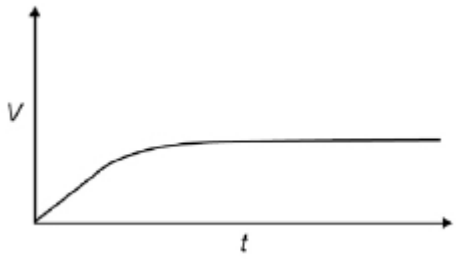
**1** Line **X** in the diagram represents the volume ($V$) of gas formed with time ($t$) in a reaction between an excess of magnesium and aqueous sulfuric acid.

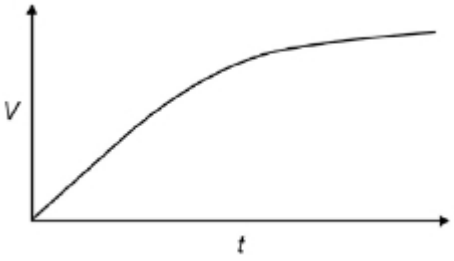



Which line represents the volume of hydrogen formed, at the same temperature and pressure, when the concentration of sulfuric acid has been halved?

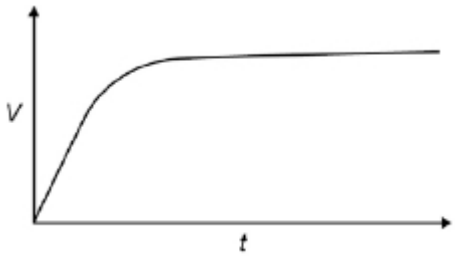
**A**



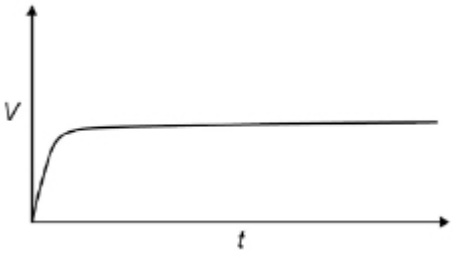

**B**




**C**

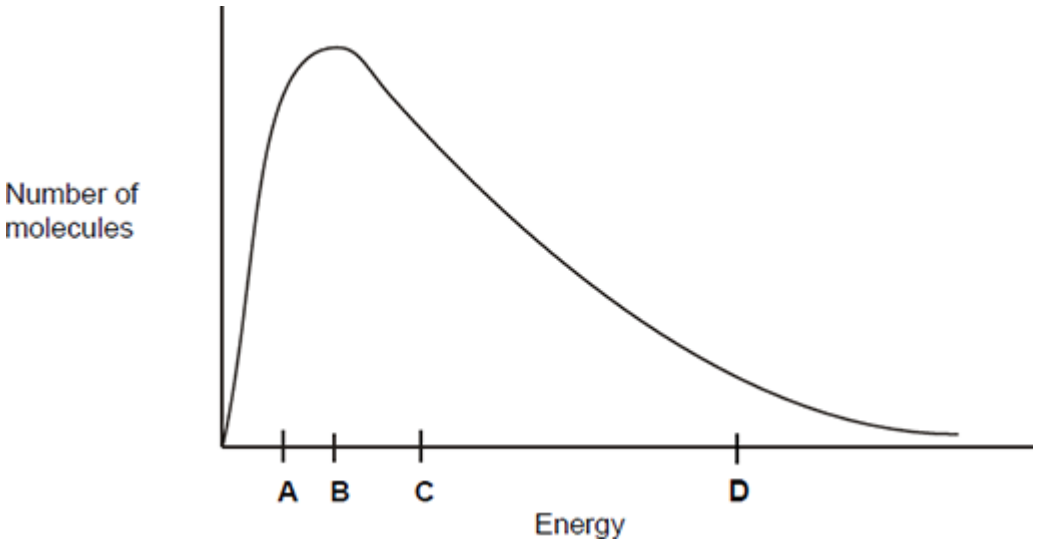



**D**



**(Total 1 mark)**

**2** This question is about the Maxwell–Boltzmann distribution of molecular energies in a sample of a gas shown in the figure below.




Which letter best represents the mean energy of the molecules?

**A** ⬭

**B** ⬭

**C** ⬭

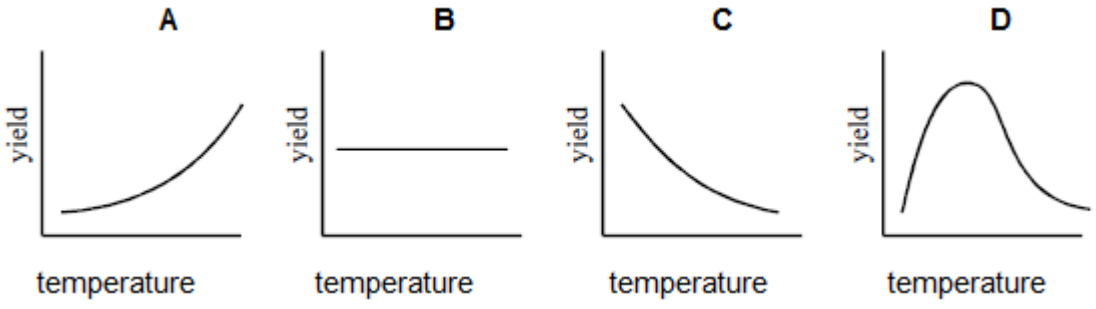
**D** ⬭

**(Total 1 mark)**

**3** Normal water and heavy water react together to form isotopically 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)**

**4** 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 $1.0 \times 10^{-3}$ mol $dm^{-3}$.

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

**A** $1.0 \times 10^{-6}$ $mol^2$ $dm^{-6}$

**B** $5.0 \times 10^{-7}$ $mol^2$ $dm^{-6}$

**C** $1.0 \times 10^{-9}$ $mol^3$ $dm^{-9}$

**D** $5.0 \times 10^{-10}$ $mol^3$ $dm^{-9}$

**(Total 1 mark)**

**5** 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)**

**6** Refer to the following reaction

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

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)**

**7** Hydrogen is produced by the reaction of methane with steam. The reaction mixture reaches a state of dynamic equilibrium.

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

Which of the following shows how the equilibrium yield of hydrogen and the value of the equilibrium constant are affected by the changes shown?

| | Change | Effect on equilibrium yield of $H_2(g)$ | Effect on value of $K_c$ | |
|---|---|---|---|---|
| **A** | Increase pressure | decrease | decrease | ⬭ |
| **B** | Add a catalyst | increase | no effect | ⬭ |
| **C** | Increase temperature | increase | increase | ⬭ |
| **D** | Remove CO(g) as formed | increase | increase | ⬭ |

**(Total 1 mark)**

**8** **A** and **B** react together in this reversible reaction.

$$\mathbf{A} + \mathbf{3B} \rightleftharpoons \mathbf{C} + \mathbf{2D}$$

A mixture of 10 mol of **A** and 10 mol of **B** were left to reach equilibrium. The equilibrium mixture contained 4 mol of **B**.

What is the total amount, in moles, of substances in the equilibrium mixture?

**A** 14 ⬭

**B** 16 ⬭

**C** 18 ⬭

**D** 20 ⬭

**(Total 1 mark)**

**9** The following equilibrium was established in a container with volume V $cm^3$ at 393 K and 200 kPa.

$$M_2(g) + R(g) \rightleftharpoons RM_2(g) \quad \Delta H = +150 \text{ kJ mol}^{-1}$$

Which change would increase the yield of $RM_2$?

**A** change the pressure to 150 kPa ⬭

**B** change the temperature to 293 K ⬭

**C** remove $RM_2$ as it is formed ⬭

**D** change the volume of the vessel to 2V $cm^3$ ⬭

**(Total 1 mark)**

**10** A pale brown mixture of $NO_2$ and $N_2O_4$ is allowed to reach equilibrium in a sealed gas syringe according to the following equation.

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

When the plunger is pushed further into the syringe the pressure increases and the mixture becomes paler in colour.

When the syringe is placed in a hot oven the mixture becomes darker in colour.

Which of the following statements is correct?

**A** $NO_2$ is brown and the forward reaction is exothermic. ⬭

**B** $NO_2$ is brown and the forward reaction is endothermic. ⬭

**C** $NO_2$ is colourless and the forward reaction is exothermic. ⬭

**D** $NO_2$ is colourless and the forward reaction is endothermic. ⬭

**(Total 1 mark)**

## Mark schemes

**1** A **[1]**

**2** C **[1]**

**3** B **[1]**

**4** D **[1]**

**5** C **[1]**

**6** A **[1]**

**7** C **[1]**

**8** C **[1]**

**9** C **[1]**

**10** A **[1]**