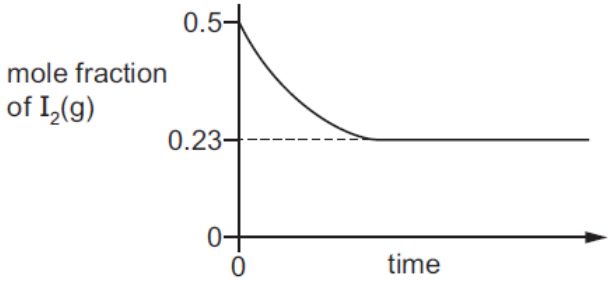
Equilibria – 2021 AS

1. Nov/2021/Paper_11/No.10

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

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

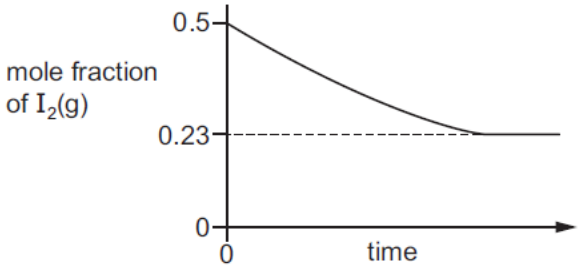
A mixture containing equal amounts of $H_2(g)$ and $I_2(g)$ is made at temperature T_1 and the composition of the mixture is monitored. A graph of the results is shown.



The experiment is repeated at a lower temperature, T_2.

Which new graph would be obtained?

A



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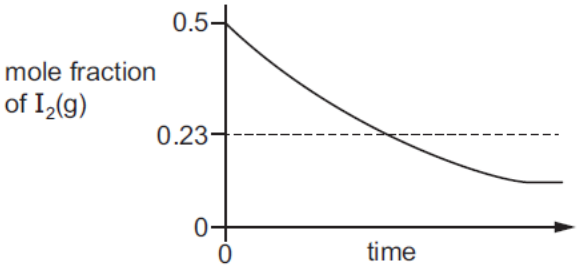

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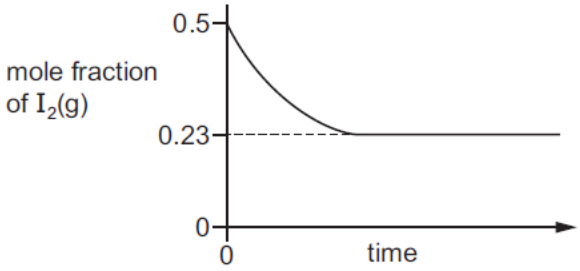

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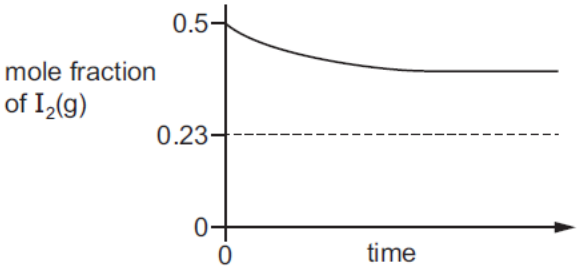
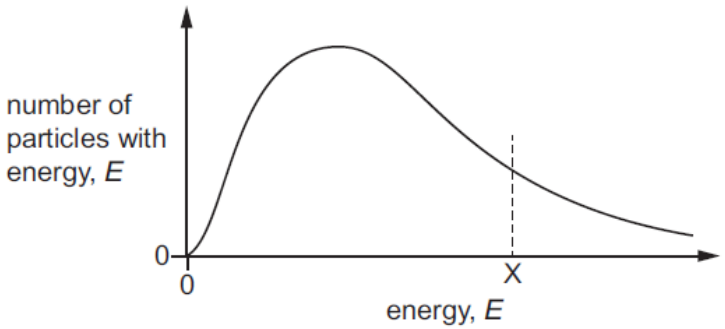


2. Nov/2021/Paper_11/No.11

The diagram shows the Boltzmann distribution of energies for a reactant gas. For a particular reaction, the activation energy is X.



Which change to the diagram occurs if an effective catalyst is added at the same temperature?

A More particles will possess higher values of *E*.

B The peak will move to the left.

C The peak will move to the right.

D The value of the activation energy decreases.

3. Nov/2021/Paper_11/No.32

Iron reacts with steam to produce hydrogen and an oxide of iron.

$$3Fe(s) + 4H_2O(g) \rightleftharpoons Fe_3O_4(s) + 4H_2(g)$$

A system containing all four substances is at equilibrium.

Which changes will decrease the mass of Fe present at equilibrium?

1 addition of steam at constant pressure

2 increase in overall pressure

3 addition of an effective catalyst

4. Nov/2021/Paper_12/No.16

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?

	smallest ⟶		largest
A	K_3	K_2	K_1
B	K_3	K_1	K_2
C	K_2	K_1	K_3
D	K_1	K_2	K_3

5. Nov/2021/Paper_12/No.31

Four solutions, each of concentration 0.1 mol dm^{-3}, were tested with a pH meter. The results are shown.

solution	formula of acid or base	pH
acid 1	CH_3CO_2H	4
acid 2	HNO_3	1
base 1	CH_3NH_2	11
base 2	NaOH	14

Which statements explain these results?

1 Acid 2 has a lower pH than acid 1 because it is more soluble.

2 Base 2 has a higher concentration of hydroxide ions in solution than base 1.

3 Acid 1 dissociates less than acid 2.

6. Nov/2021/Paper_12/No.36

Which statements about ammonium chloride are correct?

1 It reacts with hot aqueous sodium hydroxide to produce an alkaline gas.

2 In solution, it reacts with aqueous silver nitrate to produce a white precipitate.

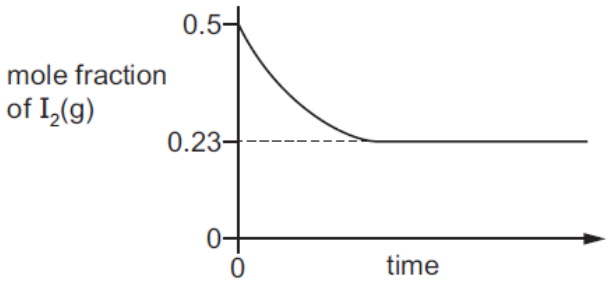
3 When solid, it reacts with concentrated sulfuric acid to produce chlorine.

7. Nov/2021/Paper_13/No.10

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

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

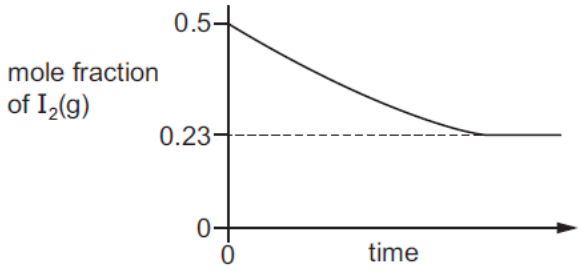
A mixture containing equal amounts of $H_2(g)$ and $I_2(g)$ is made at temperature T_1 and the composition of the mixture is monitored. A graph of the results is shown.



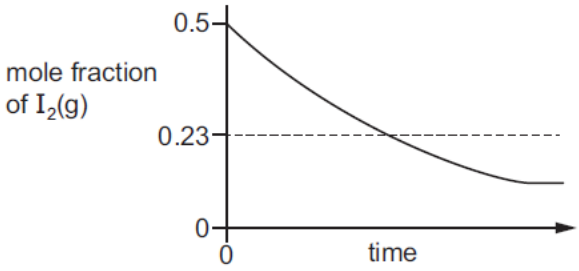
The experiment is repeated at a lower temperature, T_2.

Which new graph would be obtained?

A



B



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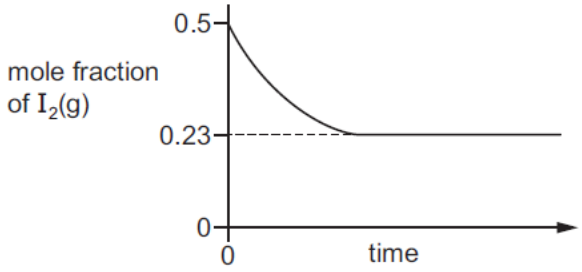
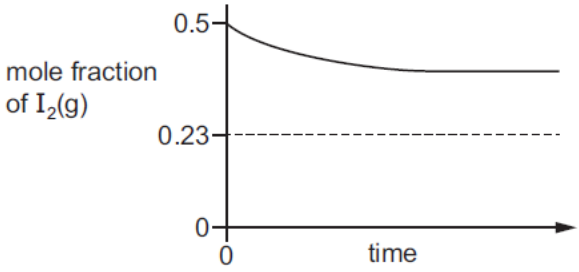
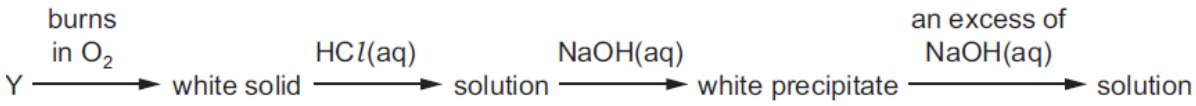


D



8. Nov/2021/Paper_13/No.11

An element, Y, reacts according to the following sequence.



What could be element Y?

A Na **B** Mg **C** Al **D** P

9. March/2021/Paper_12/No.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 $NH_3 + [Cu(H_2O)_6]^{2+} \rightarrow NH_4^+ + [Cu(H_2O)_5(OH)]^+$

10. March/2021/Paper_12/No.10

A large excess of marble chips is reacted with 25 cm^3 of 1.0 mol dm^{-3} hydrochloric acid at 40 °C.

How is the result different when the reaction is repeated with 60 cm^3 of 0.5 mol dm^{-3} hydrochloric acid at 40 °C?

A The reaction is faster and more of the products are made when the reaction is complete.

B The reaction is faster and less of the products are made when the reaction is complete.

C The reaction is slower and more of the products are made when the reaction is complete.

D The reaction is slower and less of the products are made when the reaction is complete.

11. March/2021/Paper_12/No.31

A sample of 17.15 mol HI(g) is in dynamic equilibrium with 2.27 mol $H_2(g)$ and 2.84 mol $I_2(g)$ in a volume of 1 m^3 at 764 K and 141 kPa.

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

Two equilibrium constants, K_c and K_p, can be calculated for this mixture.

Which statements about the equilibrium constants for this mixture are correct?

1 neither K_c nor K_p has any units

2 $K_c = 45.6$

3 $K_c > K_p$

12. March/2021/Paper_22/No.1

The rate of chemical reactions is affected by changes in temperature and pressure.

(a) (i) Draw a curve on the axes to show the Boltzmann distribution of energy of particles in a sample of gaseous krypton atoms at a given temperature.

Label the curve **T1** and label the axes.

[2]

(ii) On the diagram in **(a)(i)**, draw a second curve to show the distribution of energies of the krypton atoms at a higher temperature.

Label the second curve **T2**. [1]

(b) The Boltzmann distribution assumes that the particles behave as an ideal gas.

(i) State **two** assumptions of the kinetic theory as applied to an ideal gas.

1 .....

.....

2 .....

.....

[2]

(ii) 2.00 g of krypton gas, Kr(g), is placed in a sealed 5.00 dm^3 container at 120 °C.

Calculate the pressure, in Pa, of Kr(g) in the container.
Assume Kr(g) behaves as an ideal gas.

Show your working.

pressure = ... Pa [3]

(iii) State and explain the conditions at which krypton behaves most like an ideal gas.

.....

.....

.....

..... [2]

(c) Krypton reacts with fluorine in the presence of ultraviolet light to make krypton difluoride, $KrF_2(g)$.

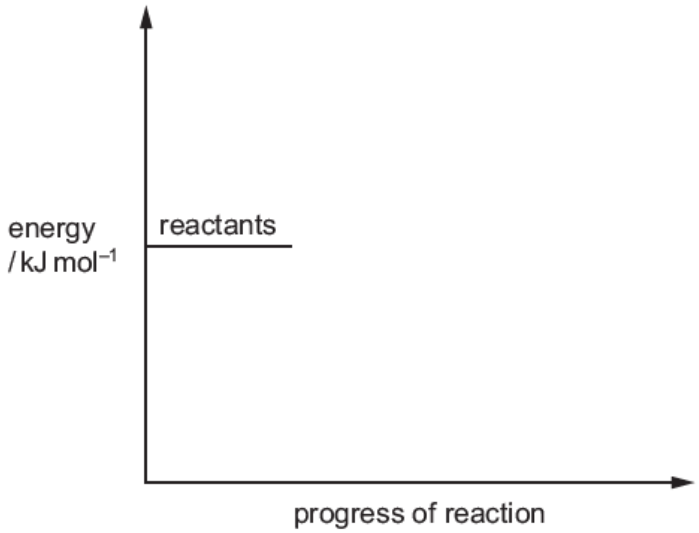
$$Kr(g) + F_2(g) \rightarrow KrF_2(g)$$

activation energy for the reaction, $E_a = +385\,kJ\,mol^{-1}$

enthalpy change of formation of KrF_2, $\Delta H_f = +60.2\,kJ\,mol^{-1}$

(i) Use this information to complete the reaction profile diagram for the formation of KrF_2. Label E_a and ΔH_f on the diagram.

Assume the reaction proceeds in one step.



[2]

(ii) Explain, in terms of activation energy, E_a, and the collision of particles, how an increase in temperature affects the rate of a chemical reaction.

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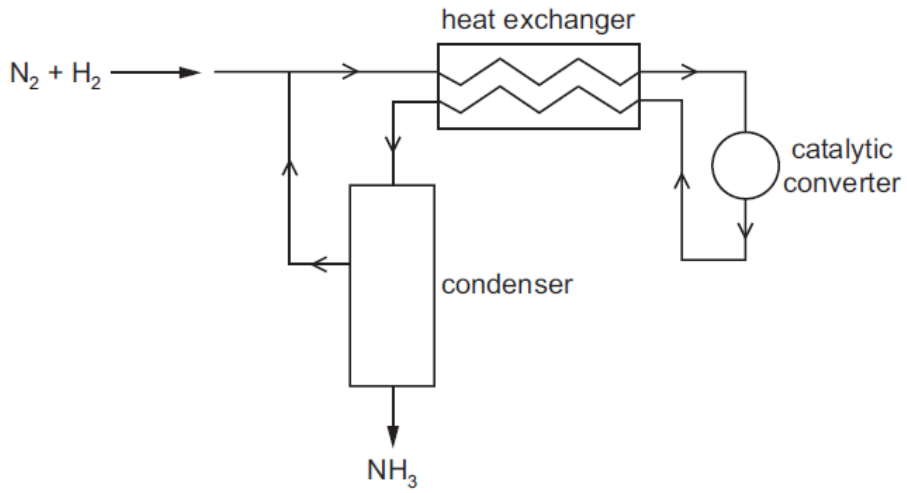
..... [2]

[Total: 14]

13. June/2021/Paper_11/No.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

14. June/2021/Paper_12/No.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

15. June/2021/Paper_12/No.14

A farmer requires a solid compound to raise the pH of the soil in a field from 5.5 to above 6.0.

Which compound could the farmer use?

A $(NH_4)_2SO_4$ **B** NH_4NO_3 **C** $Ca(OH)_2$ **D** $Ca(NO_3)_2$

16. June/2021/Paper_12/No.35

Which oxides will cause a change in pH when added to water?

1 CaO

2 Al_2O_3

3 SiO_2

17. June/2021/Paper_13/No.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 $\dfrac{(2.40)^2}{(2.32)(6.00)^3}$

18. June/2021/Paper_13/No.1

Compound X is an organic compound that contains 30.6% carbon, 3.8% hydrogen, 20.4% oxygen and 45.2% chlorine by mass.

What is the empirical formula of X?

A C_2H_3OCl **B** C_2H_4OCl **C** C_3H_4OCl **D** $C_4H_3O_2Cl_2$

19. June/2021/Paper_23/No.2(c)

(c) Methanol is made by reacting carbon monoxide with hydrogen.

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

Carbon monoxide and hydrogen react at 1.0×10^7 Pa and 200 °C. Eventually the reaction mixture reaches dynamic equilibrium.

The table shows the amounts of each species present in the mixture.

	CO(g)	$H_2(g)$	$CH_3OH(g)$
initial amount / mol	1.0	2.0	0
equilibrium amount / mol	0.030	0.060	0.97

(i) Explain what is meant by *dynamic equilibrium*.

.....

.....

..... [2]

(ii) Calculate the partial pressure of methanol vapour at equilibrium under these conditions. Show your working.

..... Pa [2]

(iii) Write an expression for the equilibrium constant, K_p, for this reaction. State the units in your answer.

K_p =

units = ... [2]