PART Y Chemistry

21 In this question, consider only the elements potassium, rubidium, calcium, strontium, bromine and iodine. Assume that there are similar trends in physical properties in Periods 4 and 5 as there are in Periods 2 and 3.

Consider the enthalpy change for the process:

$$X(g) + e^- \rightarrow X^-(g)$$

The element for which this process is most exothermic reacts with the metal with the highest first ionisation energy.

What is the relative molar mass (M_r) of the product from this reaction?

(A_r values: K = 39; Rb = 86; Ca = 40; Sr = 88; Br = 80; I = 127)

A 119

B 120

C 166

D 200

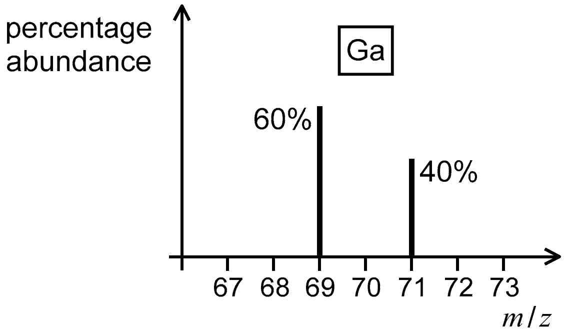
E 213

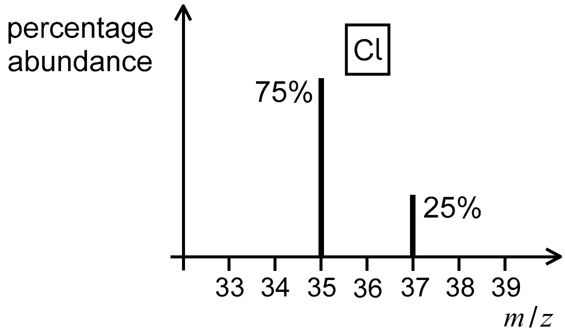
F 248

G 294

H 342

22 The following diagram gives the mass spectra of samples of the elements gallium (Ga) and chlorine (Cl).





Gaseous gallium chloride has a formula of $GaCl_3$.

The mass spectrum of gallium chloride shows peaks at different mass-to-charge ratio (m/z value).

What is the abundance ratio of the molecular ion $GaCl_3^+$ with the largest m/z value to the smallest m/z value?

A 2 : 9

B 2 : 16

C 2 : 36

D 2 : 54

E 2 : 81

23 4.00 g of bromine reacts with excess fluorine at temperatures over 150 °C to form 8.75 g of compound X only. The molecular formula of X is the same as the empirical formula.

Using the VSEPR model, what is the smallest bond angle in compound X?

(A_r values: Br = 80; F = 19)

A 120°

B in the range 114°-119°

C 109.5°

D in the range 104°-109°

E 90°

F in the range 84°-89°

24 An aqueous solution of NaCl is added to an aqueous solution containing the complex ion $Fe(H_2O)_6^{3+}$ and an equilibrium is established:

$$Fe(H_2O)_6^{3+}(aq) + 4Cl^-(aq) \rightleftharpoons FeCl_4^-(aq) + 6H_2O(l)$$

The concentration of Cl^- in the equilibrium mixture is 2.0 mol dm^{-3}.

The numerical value of the equilibrium constant, K_c, is 0.05.

The expression for K_c does not include the solvent.

What is the ratio of the concentrations $[FeCl_4^-] : [Fe(H_2O)_6^{3+}]$ in the equilibrium mixture?

(All concentrations are in mol dm^{-3}.)

A 4 : 5

B 5 : 4

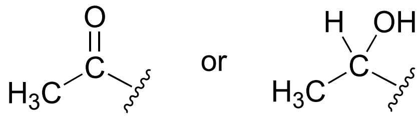
C 1 : 10

D 10 : 1

E 1 : 320

F 320 : 1

25 When organic compounds are treated with an alkaline aqueous solution of iodine, a yellow precipitate is formed by those compounds that contain either of these structural fragments:



There are 8 structurally isomeric alcohols with the molecular formula $C_5H_{12}O$.

Each of these alcohols was heated under reflux with excess acidified potassium dichromate(VI).

How many of these alcohols gave a product that would form a yellow precipitate with an alkaline aqueous solution of iodine?

A 1

B 2

C 3

D 4

E 5

F 6

G 7

26 Calcium cyanamide is a compound containing calcium, carbon and nitrogen only. It contains 50% calcium by mass, and reacts with water to form ammonia and one other product that does not contain nitrogen or hydrogen.

One mole of calcium cyanamide contains one mole of calcium.

What volume of water, in cm^3, is required to react exactly with 8.0 g of calcium cyanamide?

(A_r values: H = 1; C = 12; N = 14; O = 16; Ca = 40. Density of water is $1.0\,g\,cm^{-3}$.)

A $1.8\,cm^3$

B $2.7\,cm^3$

C $3.6\,cm^3$

D $5.4\,cm^3$

E $18\,cm^3$

F $27\,cm^3$

G $36\,cm^3$

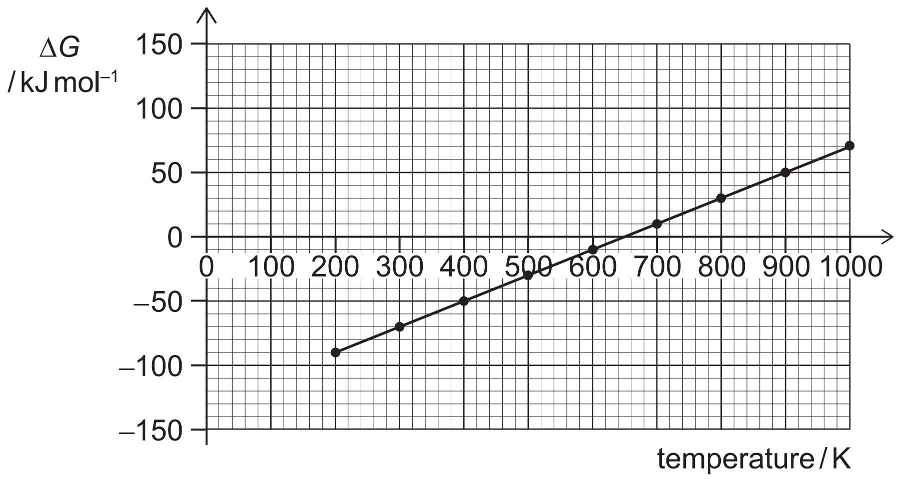
H $54\,cm^3$

27 ΔG (Gibbs free energy change), ΔH (enthalpy change) and ΔS (entropy change) are thermodynamic quantities for a reaction linked by the equation

$$\Delta G = \Delta H - T\Delta S$$

where T = temperature measured in kelvin (K).

The graph shows how ΔG, in kJ mol^{-1}, varies with temperature, in K, for a reaction at constant pressure.



Is the reaction endothermic or exothermic, and what is the value of ΔS, in J mol^{-1} K^{-1}?

(Assume that ΔH and ΔS do not vary with temperature over this range.)

	the reaction is…	ΔS / J mol^{-1} K^{-1}
A	endothermic	–0.20
B	endothermic	+0.20
C	endothermic	–200
D	endothermic	+200
E	exothermic	–0.20
F	exothermic	+0.20
G	exothermic	–200
H	exothermic	+200

28 The table gives information relating to the enthalpy change of formation of calcium chloride.

			enthalpy change / kJ mol^{-1}
$Ca(s)$	$\rightarrow$	$Ca(g)$	+190
$Ca(g)$	$\rightarrow$	$Ca^{+}(g) + e^{-}$	+590
$Ca^{+}(g)$	$\rightarrow$	$Ca^{2+}(g) + e^{-}$	+1150
$Cl_2(g)$	$\rightarrow$	$2Cl(g)$	+240
$Cl(g) + e^{-}$	$\rightarrow$	$Cl^{-}(g)$	–360
$CaCl_2(s)$	$\rightarrow$	$Ca^{2+}(g) + 2Cl^{-}(g)$	+2240

Using the data provided, what is the enthalpy change of formation of calcium chloride?

A +650 kJ mol^{-1}

B –430 kJ mol^{-1}

C –790 kJ mol^{-1}

D –910 kJ mol^{-1}

E –980 kJ mol^{-1}

F –1270 kJ mol^{-1}

G –1380 kJ mol^{-1}

H –1700 kJ mol^{-1}

29 Copper metal reacts with aqueous iron(III) ions to form aqueous iron(II) ions and aqueous copper(II) ions.

Which of the following statements can be deduced about this reaction?

A Copper(II) ions are a stronger reducing agent than iron(II) ions.

B Copper(II) ions are a stronger oxidising agent than iron(III) ions.

C Iron(II) ions are a stronger reducing agent than copper metal.

D Copper metal is a stronger oxidising agent than iron(II) ions.

E Iron(III) ions are a stronger oxidising agent than copper(II) ions.

30 Heat loss is a problem in calorimetry experiments and can lead to inaccurate results. One way to address this problem is to carry out an experiment to find the heat capacity of the calorimeter (for example, 100 g of water in a copper can) using a reaction where the molar enthalpy change is known.

A student burned $m^{(\text{ethanol})}$ grams of ethanol (relative molar mass = $M_r^{(\text{ethanol})}$) in a burner and the temperature of the water in the calorimeter rose by $\Delta T^{(\text{ethanol})}$ in °C. The molar enthalpy of combustion of ethanol is $\Delta H^{(\text{ethanol})}$.

The student then burned $m^{(\text{propanol})}$ grams of propanol (relative molar mass = $M_r^{(\text{propanol})}$) in the burner using the same calorimeter and the temperature of the water rose by $\Delta T^{(\text{propanol})}$ in °C.

Which expression gives the molar enthalpy of combustion of propanol $\Delta H^{(\text{propanol})}$?

(All other conditions for these experiments were identical.)

A $\Delta H^{(\text{ethanol})} \times \dfrac{\Delta T^{(\text{ethanol})} \times M_r^{(\text{propanol})} \times m^{(\text{ethanol})}}{\Delta T^{(\text{propanol})} \times M_r^{(\text{ethanol})} \times m^{(\text{propanol})}}$

B $\Delta H^{(\text{ethanol})} \times \dfrac{\Delta T^{(\text{ethanol})} \times M_r^{(\text{ethanol})} \times m^{(\text{ethanol})}}{\Delta T^{(\text{propanol})} \times M_r^{(\text{propanol})} \times m^{(\text{propanol})}}$

C $\Delta H^{(\text{ethanol})} \times \dfrac{\Delta T^{(\text{ethanol})} \times M_r^{(\text{ethanol})} \times m^{(\text{propanol})}}{\Delta T^{(\text{propanol})} \times M_r^{(\text{propanol})} \times m^{(\text{ethanol})}}$

D $\Delta H^{(\text{ethanol})} \times \dfrac{\Delta T^{(\text{propanol})} \times M_r^{(\text{ethanol})} \times m^{(\text{ethanol})}}{\Delta T^{(\text{ethanol})} \times M_r^{(\text{propanol})} \times m^{(\text{propanol})}}$

E $\Delta H^{(\text{ethanol})} \times \dfrac{\Delta T^{(\text{propanol})} \times M_r^{(\text{ethanol})} \times m^{(\text{propanol})}}{\Delta T^{(\text{ethanol})} \times M_r^{(\text{propanol})} \times m^{(\text{ethanol})}}$

F $\Delta H^{(\text{ethanol})} \times \dfrac{\Delta T^{(\text{propanol})} \times M_r^{(\text{propanol})} \times m^{(\text{ethanol})}}{\Delta T^{(\text{ethanol})} \times M_r^{(\text{ethanol})} \times m^{(\text{propanol})}}$

31 In an experiment to investigate diffusion, four separate identical flasks containing one of hydrogen, helium, nitrogen or neon are placed in a large cubic box filled with argon, each in a different corner. All gases, including the argon, are at atmospheric pressure.

The temperature of the box is uniform and remains constant throughout the experiment. Temperature is directly proportional to the average kinetic energy of the particles in a gas.

The stoppers of the flasks are removed simultaneously and the time is recorded when a fixed proportion of each gas reaches a detector at the centre of the box.

A second experiment is carried out under the same conditions but at a higher temperature.

(A_r values: H = 1.0; He = 4.0; N = 14; Ne = 20)

Which statement is correct?

A If hydrogen is detected in t minutes, then helium will be detected in $\sqrt{2}t$ minutes.

B The kinetic energy of every gas particle in the box will be the same at the same room temperature.

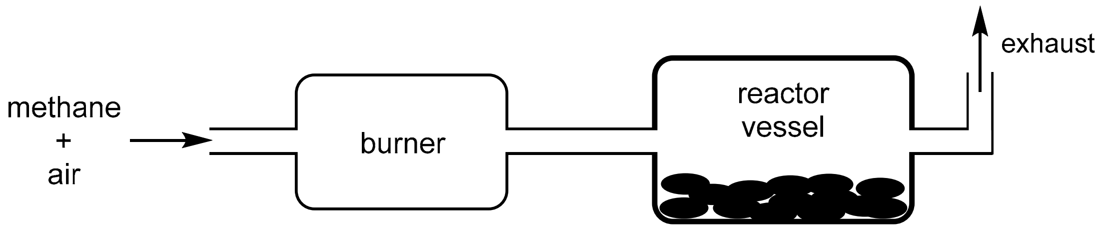
C The order in which the gases are detected at both temperatures is hydrogen, then helium, then nitrogen, and lastly neon.

D The average speed at which a helium particle travels is 5 times the speed at which an average neon particle travels.

E When the temperature of the box is increased, the average kinetic energy of the gases will decrease.

32 A high temperature reaction vessel requires a steady supply of an atmosphere free of oxygen, carbon monoxide and NO_x gases.

In order to achieve this, methane was burned in air to give a mixture of carbon dioxide, water vapour and nitrogen only.



Assume that air is composed of 20% oxygen and 80% nitrogen only by volume.

What **mass** ratio of air to methane should be supplied to the burner?

(A_r values: H = 1; C = 12; N = 14; O = 16. Assume that one mole of any gas occupies the same volume at a given temperature and pressure.)

A 2 : 1

B 2.5 : 1

C 4.5 : 1

D 5 : 1

E 9 : 1

F 18 : 1

G 20 : 1

33 In preparation for the disposal of 500 cm^3 of 4 mol dm^{-3} hydrochloric acid with a pH value of –0.6 (minus 0.6) into a drain, the following steps were taken:

step 1 The acid was diluted with 100 dm^3 water.

step 2 90 g of calcium carbonate powder was added which completely reacted.

step 3 The resulting solution was diluted with water to give a final volume of 500 dm^3.

What is the final pH value of the solution?

(M_r value: $CaCO_3$ = 100. All pH values were measured at the same temperature.)

A 2.9

B 3.4

C 3.6

D 4.4

E 4.6

F 5.4

G 6.0

H 7.0

34 Lutetium (Lu) is a metallic element which forms compounds in which lutetium always has the same oxidation state.

When 3.50 g of lutetium is heated and burned in excess oxygen, 360 cm^3 of oxygen, measured at room temperature and pressure, is needed for complete reaction to form lutetium oxide.

When 3.50 g of lutetium reacts completely with dilute sulfuric acid, hydrogen and aqueous lutetium sulfate are produced. The salt is extracted from solution and allowed to crystallise into a white solid.

The solid is a hydrated salt with a 1 **:** 1 molar ratio of water to salt.

What is the maximum mass of hydrated salt that could be made from 3.50 g of lutetium?

(A_r values: Lu = 175; S = 32; O = 16; H = 1. Assume that one mole of any gas occupies 24 dm^3 at room temperature and pressure.)

A 5.42 g

B 5.78 g

C 6.38 g

D 6.56 g

E 9.26 g

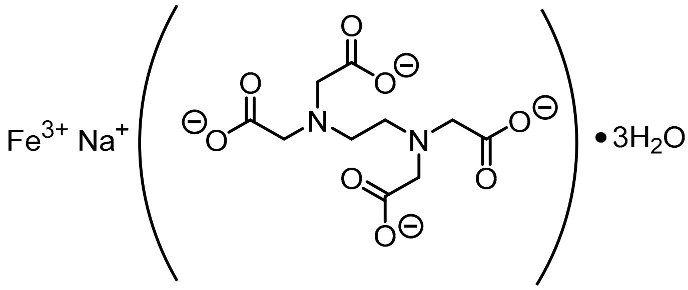
F 9.62 g

G 12.76 g

H 13.12 g

35 Sodium feredetate trihydrate and iron(II) sulfate can both be used to treat iron deficiency.

The formula for sodium feredetate trihydrate is:



Sodium feredetate trihydrate is used as a solution. 5.00 cm^3 of this solution contains 210.5 mg of sodium feredetate trihydrate.

Iron(II) sulfate is used in tablet form. One iron tablet contains 63.0 mg of iron(II) ions.

What volume of sodium feredetate trihydrate solution would give the same mass of iron as one iron(II) sulfate tablet?

(A_r values: H = 1.0; C = 12; N = 14; O = 16; Na = 23; Fe = 56)

A 0.450 cm^3

B 2.25 cm^3

C 9.81 cm^3

D 10.29 cm^3

E 10.93 cm^3

F 11.25 cm^3

36 Three half-equations involved in the oxidation of ethanol to ethanoic acid are:

$$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$$

$$CH_3CH_2OH \rightarrow CH_3CHO + 2e^- + 2H^+$$

$$CH_3CHO + H_2O \rightarrow CH_3COOH + 2e^- + 2H^+$$

A flask contains 0.345 g of ethanol. An excess of dilute sulfuric acid is added to the flask.

A separate flask contains 0.200 mol dm^{-3} aqueous dichromate ions, $Cr_2O_7^{2-}$.

What volume of aqueous dichromate is needed to exactly convert all the ethanol to ethanoic acid?

(M_r value: CH_3CH_2OH = 46)

A 6.25 cm^3

B 9.38 cm^3

C 12.50 cm^3

D 25.00 cm^3

E 37.50 cm^3

F 56.25 cm^3

G 112.50 cm^3

37 V is a compound with empirical formula CH_2. It undergoes an addition reaction with hydrogen bromide, producing compound W.

W reacts with potassium cyanide to produce organic compound X which contains approximately $\frac{1}{6}$ by mass of nitrogen.

W also reacts with warm aqueous sodium hydroxide to give organic compound Y.

Y reacts with hot acidified potassium dichromate(VI) to produce organic compound Z.

Z does not react with aqueous sodium carbonate, nor does it react with Tollens' reagent.

Which of the following is a possible identity for W?

(A_r values: H = 1; C = 12; N = 14)

A 1-bromobutane

B 1-bromopentane

C 1-bromopropane

D 2-bromo-2-methylpropane

E 2-bromobutane

F 2-bromo-2-methylbutane

G 2-bromopropane

H 3-bromopentane

38 A student is planning an experiment to determine the percentage of iron in a 3 g sample of the iron ore haematite, which contains Fe_2O_3 as the only iron-containing species and other material which will not react in this experiment. The sample contains approximately 50% iron by mass.

The student's plan is:

step 1 Make a solution of Fe^{3+} ions by reacting iron(III) oxide with concentrated acid.

step 2 Reduce the Fe^{3+} ions to Fe^{2+} ions using a solution of tin(II) chloride.

step 3 Make up the solution containing Fe^{2+} to 250 cm^3 by adding water.

step 4 Titrate 25 cm^3 portions using potassium dichromate(VI) solution, $K_2Cr_2O_7$.

The equations for the reactions occurring are:

$$Fe_2O_3 + 6H^+ \rightarrow 2Fe^{3+} + 3H_2O$$

$$Sn^{2+} + 2Fe^{3+} \rightarrow Sn^{4+} + 2Fe^{2+}$$

$$Fe^{2+} \rightarrow Fe^{3+} + e^-$$

$$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$$

In order to obtain titre values of between 15 cm^3 and 35 cm^3, what concentration of potassium dichromate(VI), in $mol\,dm^{-3}$, should the student use?

(A_r value: Fe = 56)

A 0.02 $mol\,dm^{-3}$

B 0.04 $mol\,dm^{-3}$

C 0.10 $mol\,dm^{-3}$

D 0.20 $mol\,dm^{-3}$

E 0.50 $mol\,dm^{-3}$

F 1.00 $mol\,dm^{-3}$

39 0.92 g of gaseous dinitrogen tetroxide, $N_2O_4(g)$, is placed in a syringe with a free moving piston at 25 °C and atmospheric pressure.

At 25 °C, gaseous dinitrogen tetroxide dissociates and forms an equilibrium mixture with gaseous nitrogen dioxide, $NO_2(g)$, only.

At equilibrium, the total volume of gas in the syringe is 288 cm^3.

What percentage of the dinitrogen tetroxide has dissociated?

(A_r values: N = 14; O = 16. Assume that, for all of the gases, one mole of gas occupies a volume of 24 dm^3 at 25 °C and atmospheric pressure.)

A 10%

B 20%

C 30%

D 40%

E 50%

F 60%

G 70%

H 80%

40 Fluoride ions can be added to drinking water to improve dental health.

The recommended concentration of fluoride ions in drinking water for observable health benefits is between 1.0 and 1.5 ppm by mass.

The concentration of fluoride ions in a full 10 million litre water storage reservoir is 0.5 ppm.

The following three compounds can be used to supply fluoride ions to water:

sodium fluoride (NaF, $M_r = 42$)

hexafluorosilicic acid (H_2SiF_6, $M_r = 144$)

sodium fluorosilicate (Na_2SiF_6, $M_r = 188$)

Assume that all the fluorine present in the compounds ionises in water to form fluoride ions.

Which of the following treatments can be added to increase the fluoride ion concentration to within the recommended range?

(A_r value: F = 19. Density of water is 1 g cm^{-3}. 1 ppm = 1 part per million = 0.0001%.)

A 6.30 kg of sodium fluoride (NaF)

B 7200 g of hexafluorosilicic acid (H_2SiF_6)

C 14 400 g of hexafluorosilicic acid (H_2SiF_6)

D 18.8 g of sodium fluorosilicate (Na_2SiF_6)

E 37.6 kg of sodium fluorosilicate (Na_2SiF_6)

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