PART Y Chemistry

21 A Group 1 metal hydrogencarbonate contains the HCO_3^- ion and decomposes at 200 °C.

When dilute hydrochloric acid is added to the residue from the thermal decomposition of this metal hydrogencarbonate, a gas is released that turns limewater cloudy. The residue also gives a yellow-orange colour in a flame test.

8.4 g of this metal hydrogencarbonate is heated to constant mass at 200 °C.

How much mass is lost in this reaction?

(A_r values: H = 1; C = 12; O = 16; Li = 7; Na = 23; K = 39)

A 2.2 g

B 2.6 g

C 3.1 g

D 4.0 g

E 4.4 g

F 5.3 g

G 6.2 g

22 Which of the following statements is correct for the bond angle (θ) in gaseous germanium(II) chloride, $GeCl_2$, molecules as predicted by the VSEPR model?

A $\theta = 90°$

B $90° < \theta < 120°$

C $\theta = 120°$

D $120° < \theta < 180°$

E $\theta = 180°$

23 Propanal can be reduced to propan-1-ol with hydrogen gas at high pressure and a platinum catalyst.

Radioactive propan-1-ol can be made if the hydrogen gas is replaced by pure tritium gas. Tritium, ^{3}H, is the radioactive isotope of hydrogen.

All of the atoms other than ^{3}H in the radioactive propan-1-ol are the most abundant isotope for the element. The most abundant isotopes of carbon, hydrogen and oxygen are ^{12}C, ^{1}H and ^{16}O.

How many neutrons are there in one molecule of this radioactive propan-1-ol?

A 26

B 28

C 30

D 32

E 34

F 40

G 42

24 A sample of hydrated cobalt(II) sulfate, $CoSO_4 \cdot xH_2O$, with a mass of 5.62 g, was heated to convert the sample completely to 3.10 g of anhydrous cobalt(II) sulfate.

What is the value of x?

(A_r values: H = 1.0; O = 16.0; S = 32.1; Co = 58.9)

A 2

B 3

C 4

D 5

E 6

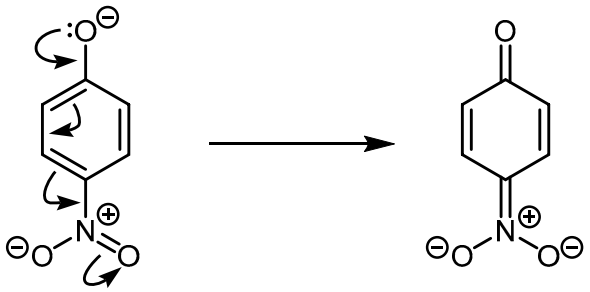
F 7

G 8

H 9

25 Which of the following does **not** give the species shown?

A



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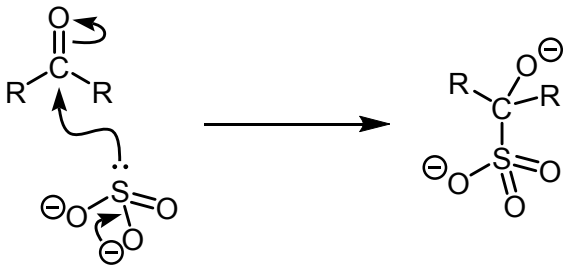

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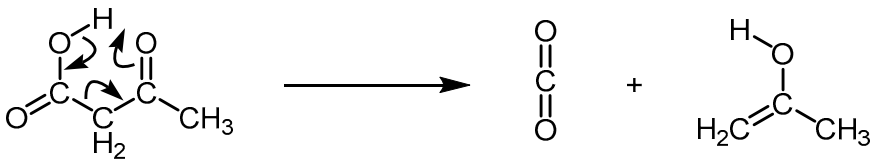

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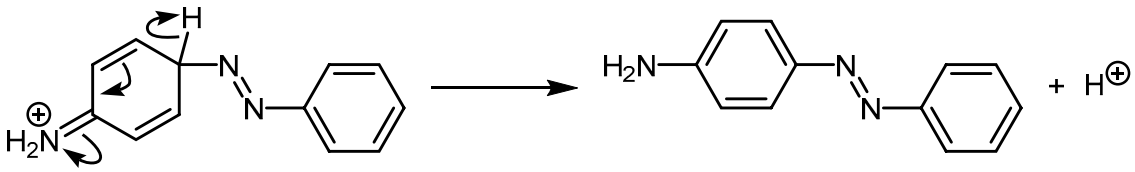
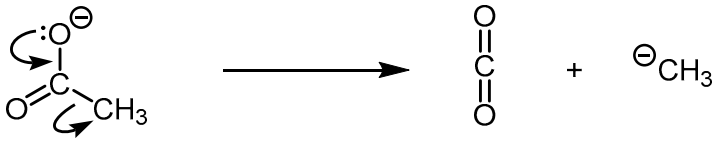


E



26 0.4 mol of a halogenoalkane reacted completely with hot, ethanolic potassium hydroxide to give 28 g of a single organic product X in 100% yield.

What percentage of all of the structural isomers with both the same functional group and molecular formula as X would show geometric (*E*/*Z*) isomerism?

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

A 17%

B 20%

C 25%

D 33%

E 40%

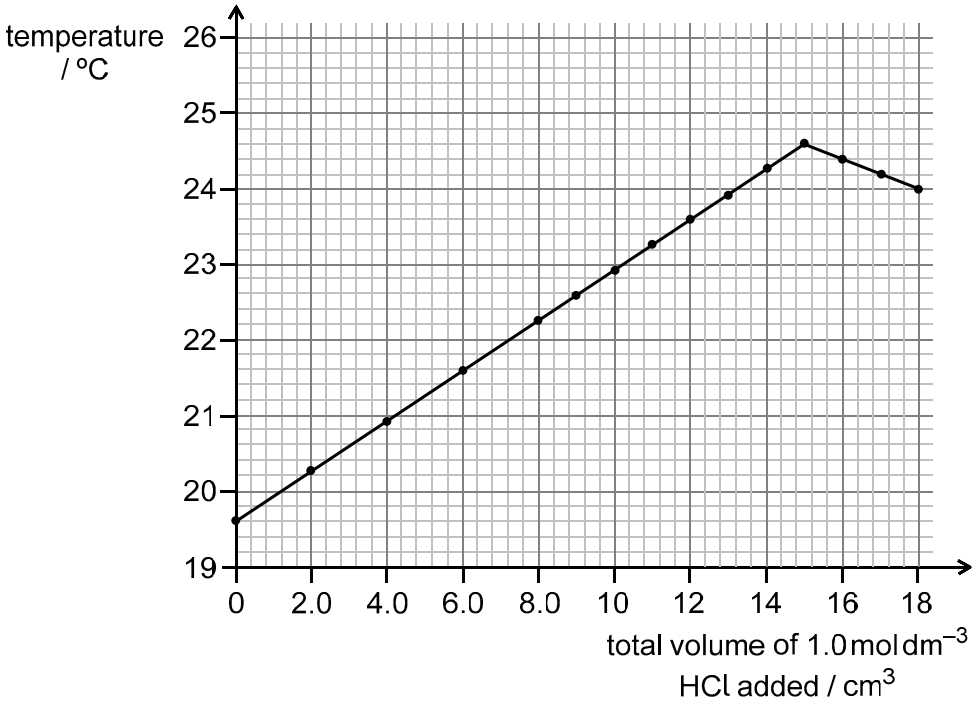
F 50%

27 25.0 cm^3 of sodium hydroxide solution is placed in a polystyrene cup with a thermometer.

1.00 mol dm^{-3} hydrochloric acid is added from a burette to the stirred solution of sodium hydroxide.

Both solutions are at the same temperature before mixing.

The temperature is recorded each time a measured amount of hydrochloric acid is added, and the data is plotted on a graph.



Assuming that no heat is lost from the cup, what is the enthalpy change of reaction when one mole of aqueous sodium hydroxide is neutralised?

(Assume that all solutions have density 1.0 g cm^{-3} and specific heat capacity 4.2 J g^{-1} °C^{-1}.)

A –56.0 kJ

B –49.3 kJ

C –35.0 kJ

D –33.6 kJ

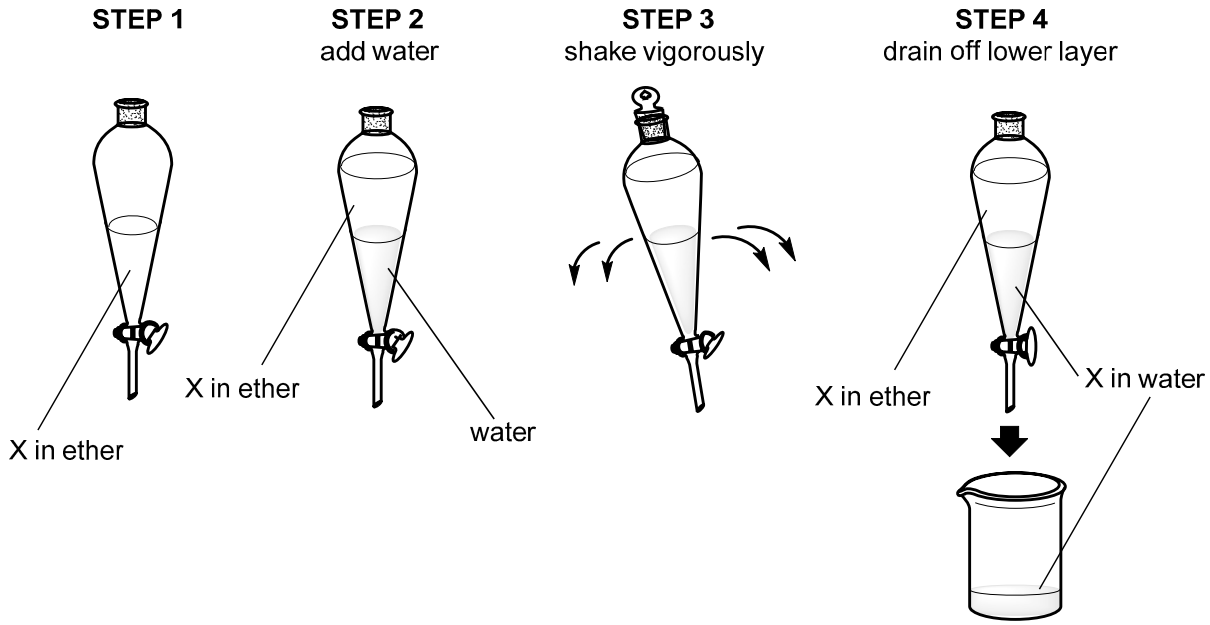
E –21.0 kJ

28 Consider the distribution of a solute X between two immiscible solvents: water and ether.

$$X(aq) \rightleftharpoons X(ether)$$

The equilibrium constant, K_c, is 0.15 at 25 °C.

50 cm^3 of a solution of X in ether at 25 °C contains 21.5 g of X. 100 cm^3 of water is added, shaken with the ether solution and allowed to reach equilibrium at 25 °C.



What is the maximum mass of X that can be transferred into the aqueous layer?

A 4.96 g

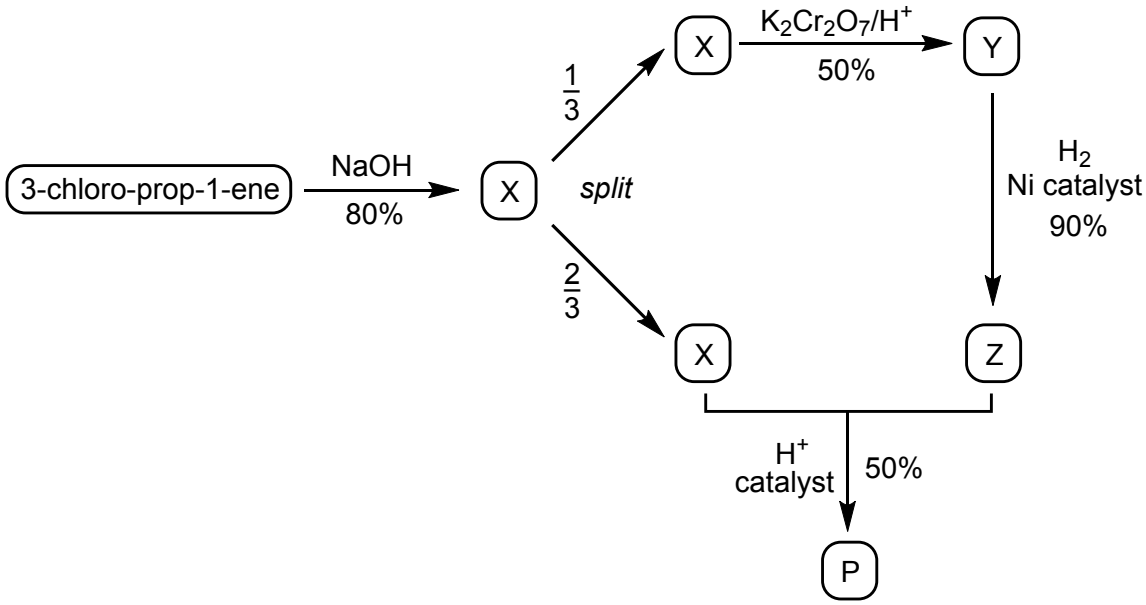
B 14.3 g

C 18.7 g

D 20.0 g

E 20.5 g

29



5.0 mol of 3-chloro-prop-1-ene (M_r = 76.5) was reacted with excess sodium hydroxide to form a single product X in 80% yield.

One third of compound X was heated with excess acidified potassium dichromate(VI) under reflux to form a single product Y in 50% yield.

All of compound Y was reacted with hydrogen gas at high temperature in the presence of nickel to form a single product Z in 90% yield.

The remaining quantity of compound X was reacted with all of compound Z in the presence of an acid catalyst to form product P in 50% yield.

What is the maximum mass of product P that could be produced from this synthesis?

(A_r values: H = 1; C = 12; O = 16; Cl = 35.5)

A 2.74 g

B 5.48 g

C 23.0 g

D 34.2 g

E 114 g

F 123 g

G 152 g

30 Iron(II) sulfate is used as a moss treatment on lawns and sports pitches. The recommended amount of iron is 2.5 kg per 10^4 m^2.

Analysis of a particular sports pitch showed it to contain 0.05 g of iron per m^2.

A pitch care company supplies three hydrated formulations:

- $FeSO_4 \cdot 7H_2O$ which contains 20% of iron by mass
- $FeSO_4 \cdot 4H_2O$ which contains 25% of iron by mass
- $FeSO_4 \cdot H_2O$ which contains 33% of iron by mass

A 25 kg sack of one of the iron(II) sulfate formulations is to be used on the sports pitch but unfortunately it has lost its label. A small sample was heated to constant mass to form a white solid, and the mass of the sample decreased by more than 40% in this process.

The sports pitch is 90 m long and 60 m wide.

What mass of the iron(II) sulfate formulation (in kg) should be added to ensure that the iron content is at the recommended level?

(M_r values: $FeSO_4$ = 152; H_2O = 18)

A 1.08 kg

B 1.35 kg

C 3.60 kg

D 4.32 kg

E 5.40 kg

F 6.75 kg

31 A compound contains potassium cations, and anions that contain only boron and fluorine. Each anion contains one boron atom.

0.630 g of this compound contains 0.195 g of potassium and 0.055 g of boron.

What is the shape of the anions in this compound?

(A_r values: B = 11; F = 19; K = 39)

A linear

B bent (V-shaped)

C trigonal planar

D trigonal pyramidal

E tetrahedral

F square planar

32 The first ionisation energy of five elements is measured.

Which row matches the five elements to their first ionisation energy?

	first ionisation energy / kJ mol^{-1}				
	577	736	1000	1060	1680
A	F	Mg	Al	P	S
B	F	P	S	Mg	Al
C	F	P	S	Al	Mg
D	Mg	Al	S	P	F
E	Mg	Al	P	S	F
F	Al	Mg	P	S	F
G	Al	Mg	S	P	F
H	S	P	Al	Mg	F

33 A yellow precipitate is formed when alkaline aqueous iodine reacts with alcohols that have the structure R-CH(OH)CH_3, where R is a carbon chain or H.

There are a number of structural isomers with the molecular formula $C_5H_{12}O$ that are alcohols.

Of these structural isomeric alcohols:

(i) how many will form a yellow precipitate when reacted with alkaline aqueous iodine;

(ii) how many, following mild oxidation and immediate distillation, will produce a silver mirror with Tollens' reagent?

	(i) *forms yellow precipitate*	(ii) *produces silver mirror*
A	1	1
B	2	3
C	2	4
D	2	7
E	3	3
F	3	4
G	3	7
H	4	4

34 The standard enthalpy change of formation of hydrogen iodide is +26 kJ mol^{-1}.

For the reaction of gaseous iodine with hydrogen

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

the enthalpy change of reaction can be calculated using bond enthalpy values.

The bond enthalpies are:

bond	*bond enthalpy* / kJ mol^{-1}
H – H	436
I – I	151
H – I	299

The sublimation of iodine is represented by: $I_2(s) \rightarrow I_2(g)$

Using the data provided, what is the enthalpy change for the sublimation of iodine?

(All data is given at room temperature and pressure.)

A –262 kJ mol^{-1}

B –236 kJ mol^{-1}

C –41 kJ mol^{-1}

D +37 kJ mol^{-1}

E +41 kJ mol^{-1}

F +63 kJ mol^{-1}

G +236 kJ mol^{-1}

35 Sodium hydrogencarbonate, $NaHCO_3$, and sodium carbonate are both used as antacids. They react with hydrochloric acid in the stomach to form the same products.

The contents of a person's stomach has a pH of 1.0, which is a concentration of $0.1\,mol\,dm^{-3}$ HCl. The stomach contained $80\,cm^3$ of aqueous solution when the pH was measured.

Which of the following amounts of sodium hydrogencarbonate would bring the stomach contents into the normal range of pH 2.0-3.0?

(A_r values: H = 1; C = 12; O = 16; Na = 23)

A 0.0038 mol

B 0.0075 mol

C 0.0080 mol

D 0.016 mol

E 0.095 mol

36 X is a **di**carboxylic acid. When in aqueous solution, 2.36 g of X reacts with excess sodium carbonate to produce 480 cm^3 of carbon dioxide, measured at room temperature and pressure. Assume that no gas dissolves in the water present.

Y is a liquid organic compound containing only one functional group. 1 mol of Y reacts exactly with 1 mol of sodium, giving off a gas that pops with a lighted splint. Aqueous Y does not change the colour of blue or red litmus papers.

When 50.0 cm^3 of gaseous Y is combusted in excess oxygen, 150 cm^3 of carbon dioxide and 200 cm^3 of water vapour are the only products formed. All volumes are measured at the same temperature and pressure.

When heated in the presence of concentrated sulfuric acid, 1 mol of X reacts completely with 2 mol of Y to give 1 mol of organic product Z. Water is also produced in the reaction.

What is the relative molar mass of Z?

(A_r values: H = 1; C = 12; O = 16. Assume that one mole of gas occupies 24 dm^3 at room temperature and pressure.)

A 101

B 160

C 166

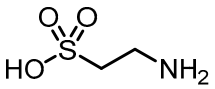
D 170

E 202

F 220

37 Cats are unable to synthesise the amino acid taurine in their bodies, so they must obtain it from their food. It is often added to cat food as an additive.

Taurine is a monoprotic acid with the following molecular structure:



$M_r = 125$

Dietary studies suggest that a cat should consume 10 mg of taurine per kilogram of body mass per day.

Brand X cat food contains taurine at a level of 0.008% by mass, but this level is too low for a cat to acquire a sufficient amount from a healthy amount of food.

Magnesium taurate is an ionic salt which liberates taurine in the body. 8 cm^3 of a 0.5 mol dm^{-3} aqueous solution of magnesium taurate was added to a 10 kg bag of brand X cat food and thoroughly mixed.

A particular cat bowl can hold a 50 g serving of cat food. A particular cat of mass 4000 g always eats a full serving.

What is the minimum number of bowls of cat food that this cat must eat to ensure that it has consumed its daily requirement of taurine?

(Assume that the addition of the solution does not significantly alter the total mass of the bag of cat food.)

A 2

B 3

C 4

D 5

E 6

F 7

G 8

38 Analysis of hydrocarbon P showed it to contain 0.60 g of carbon and 0.10 g of hydrogen, and to have a relative molecular mass of 70.

P reacts with hydrogen bromide to form a mixture of Q and R. However, the main product was Q.

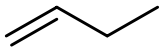
Q reacts with warm, aqueous sodium hydroxide to form S.

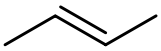
S reacts with warm, acidified potassium dichromate(VI) to form T. T does not produce a silver mirror with Tollens' reagent and does not produce bubbles when sodium carbonate is added.

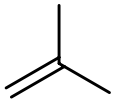
S undergoes dehydration on reaction with hot, concentrated sulfuric acid to form the original hydrocarbon P and a new compound U. Both P and U do not have stereoisomers.

What is the structure of compound U?

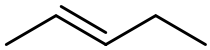
(A_r values: H = 1; C = 12)

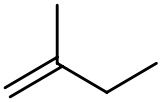
A 

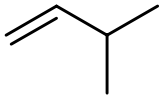
B 

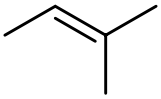
C 

D 

E 

F 

G 

H 

39 Lanthanum iodate(V), $La(IO_3)_3$, decomposes when heated to 600 °C to give a product that contains the ion Q.

An **unbalanced** ionic equation for the reaction is:

$$IO_3^- \rightarrow \text{ion Q} + I_2 + O_2$$

Ion Q contains only iodine in the +7 oxidation state and oxygen in the −2 oxidation state.

The oxidation state of the lanthanum does not change in the reaction.

0.005 mol of $La(IO_3)_3$ is fully decomposed by heating. The iodine produced is titrated against a 0.4 mol dm^{-3} solution of sodium thiosulfate ($Na_2S_2O_3$). 30.0 cm^3 of the sodium thiosulfate solution is needed to reach the end-point. The equation for the reaction between iodine and sodium thiosulfate is:

$$I_2 + 2Na_2S_2O_3 \rightarrow 2NaI + Na_2S_4O_6$$

What is the formula of the product that contains ion Q?

A $LaIO_5$

B $LaIO_6$

C $La(IO_4)_3$

D $La_3(IO_6)_5$

E $La_5(IO_4)_3$

F $La_5(IO_6)_3$

40 Consider the following chemical equation:

$$v\mathrm{Q} + w\mathrm{P_4} + x\mathrm{H_2O} \rightarrow y\mathrm{PH_4I} + z\mathrm{H_3PO_4}$$

where Q is a binary compound.

The molecules of Q are hexatomic and contain phosphorus in the +2 oxidation state.

Using the lowest integer values for all the coefficients v, w, x, y and z, what is the value of w when the equation is balanced?

A 1

B 2

C 13

D 16

E 24

F 26

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