

Physical Chemistry

Question Paper 1

Level	Pre U
Subject	Chemistry
Exam Board	Cambridge International Examinations
Topic	Physical Chemistry
Booklet	Question Paper 1

Time Allowed: 59 minutes

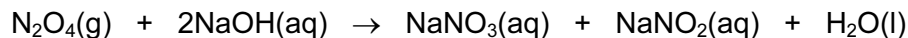
Score: /49

Percentage: /100

Grade Boundaries:

Basic Calculations

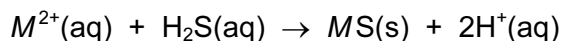
1. N_2O_4 is a poisonous gas. It can be disposed of safely by reaction with sodium hydroxide.



What is the minimum volume of 0.5 mol dm^{-3} $\text{NaOH}(\text{aq})$ needed to dispose of 0.02 mol of N_2O_4 ?

- A** 8 cm^3 **B** 12.5 cm^3 **C** 40 cm^3 **D** 80 cm^3

2. Hydrogen sulfide, H_2S , can be used to identify a range of metal ions in solution because they form insoluble sulfides. For a metal ion, M^{2+} , the reaction can be summarised by the equation.



Which two terms accurately describe this reaction?

- A** disproportionation and decomposition
B disproportionation and precipitation
C precipitation and acid-base
D redox and acid-base

3. Bone contains calcium salts and other material. When bone is strongly heated in air, calcium oxide is the only solid residue.

When 25.0 g of a bone sample is strongly heated in air, 7.0 g of solid residue remains.

What is the percentage by mass of calcium in the bone sample?

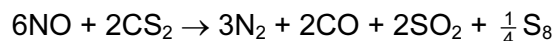
- A** 10.0% **B** 14.0% **C** 20.0% **D** 28.0%

4. When iron reacts with aqueous iron(III) ions, iron(II) ions are formed as the only product.

A final mixture, after the reaction has taken place, contains equal numbers of moles of $\text{Fe}^{2+}(\text{aq})$ and $\text{Fe}^{3+}(\text{aq})$. Assuming the reaction has gone to completion, how many moles of $\text{Fe}(\text{s})$ and $\text{Fe}^{3+}(\text{aq})$ were in the starting mixture?

	moles of $\text{Fe}(\text{s})$	moles of $\text{Fe}^{3+}(\text{aq})$
A	1	2
B	1	3
C	1	5
D	2	3

5. An exciting chemical demonstration is the 'barking dog'. An equation which describes the reaction is shown.



Carbon disulfide, CS_2 , is a liquid with a density of 1.26 g cm^{-3} .

Which mass of sulfur would be formed from 5.00 cm^3 of CS_2 if the reaction proceeded with 100 % yield?

- A** 0.330g **B** 1.67g **C** 2.65g **D** 5.31g

6. Hot concentrated nitric acid, HNO_3 , is a powerful oxidising agent.

In its reaction with carbon, the oxidation number of carbon increases by 4 and the oxidation number of nitrogen decreases by 1.

How many moles of nitric acid are needed to oxidise one mole of carbon in this reaction?

- A** 1 **B** 2 **C** 3 **D** 4

7. How many neutrons are present in 0.13 g of ^{13}C ?
[L = the Avogadro constant]

- A** 0.06L **B** 0.07L **C** 0.13L **D** 0.91L

8. Phosphorus sulfide, P_4S_3 , is used in small amounts in the tips of matches. On striking a match this compound burns to produce an oxide of phosphorus in the +5 oxidation state and an oxide of sulfur in the +4 oxidation state.

How many moles of oxygen gas are needed to burn one mole of P_4S_3 in this way?

- A** 6 **B** 7.5 **C** 8 **D** 16

9. Sodium thiosulfate reduces iodine to iodide ions.

In this reaction, how many moles of electrons are supplied per mole of the thiosulfate ions?

- A** 1 **B** 2 **C** 3 **D** 4

10. The metal niobium, Nb, has a relative atomic mass of 92.9 and is used in various stainless steel alloys. It is made by reducing niobium chloride with sodium. In this reaction, 54.08 g of niobium chloride produces 18.58 g of niobium.

What is the formula of the niobium chloride used?

- A** $NbCl_2$ **B** $NbCl_3$ **C** $NbCl_4$ **D** $NbCl_5$

15. An ionic compound Q

- has an empirical formula NH_2O ,
- reacts with $\text{NaOH}(\text{aq})$ to produce ammonia gas.

How many electrons are present in the anion of Q?

- A** 23 **B** 24 **C** 31 **D** 32

16. Which set of solid elements contains a simple molecular structure, a giant covalent (macromolecular) structure and a giant metallic structure?

- A** Mg, P, S **B** P, Si, C **C** S, P, Si **D** S, Si, Al

Energy

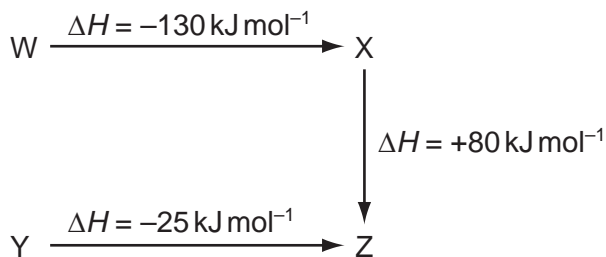
17. The interhalogen compound BrF_3 is a volatile liquid which autoionises.



The electrical conductivity of BrF_3 decreases with increasing temperature.

Which statement is correct?

- A The autoionisation process is endothermic and the shape of the cation is linear.
 - B The autoionisation process is endothermic and the shape of the cation is non-linear.
 - C The autoionisation process is exothermic and the shape of the cation is linear.
 - D The autoionisation process is exothermic and the shape of the cation is non-linear.
18. The diagram represents the energy changes for some reactions.

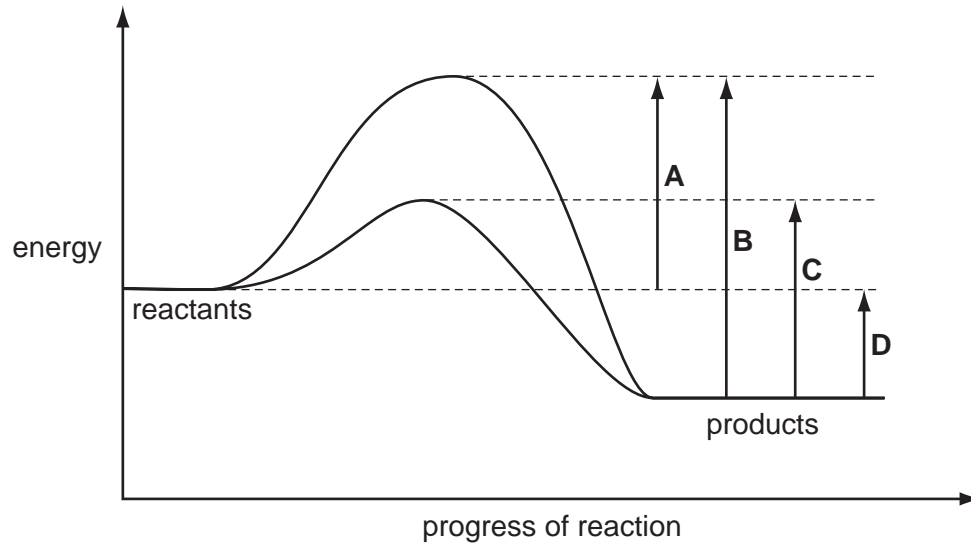


What are the natures of the conversions $\text{W} \rightarrow \text{Y}$, $\text{Y} \rightarrow \text{X}$ and $\text{Z} \rightarrow \text{W}$?

	$\text{W} \rightarrow \text{Y}$	$\text{Y} \rightarrow \text{X}$	$\text{Z} \rightarrow \text{W}$
A	exothermic	endothermic	endothermic
B	exothermic	exothermic	endothermic
C	endothermic	exothermic	exothermic
D	endothermic	endothermic	exothermic

19. The diagram shows the energy profile for a reaction both with and without a catalyst present.

What is the activation energy of the uncatalysed reverse reaction?

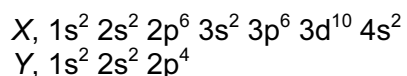


Orbitals and Electron Spin

20. How many different orbitals are there in the 3s, 3p and 3d sub-shells respectively?

- A 1, 3, 5
- B 1, 4, 9
- C 2, 6, 10
- D 2, 8, 18

21. The atoms X and Y have the following electronic configurations.



What is the formula of the compound they are likely to form?

- A $X^{2+}(Y^-)_2$
- B $X^{2+}Y^{2-}$
- C XY_4
- D X_2Y_4

22. How many subshells and orbitals are there in the third shell?

	subshells	orbitals
A	2	4
B	2	8
C	3	5
D	3	9

23. Which atom has the highest ratio of unpaired electrons to paired electrons in its ground state?

- A boron
- B carbon
- C nitrogen
- D oxygen

24. Which compound is composed of a cation and anion(s) that do **not** contain the same number of electrons as each other?

- A** LiH **B** NaOH **C** NH₄F **D** TiCl₃

25. In the compound Co(ClO₃)₂, the Cl atom has an oxidation state of +5.

How many *d*-orbital electrons are present in the cobalt ion in this compound?

- A** 5 **B** 7 **C** 8 **D** 9

26. The information relates to element Z.

- Z is in Period 3 of the Periodic Table.
- Z has a lower electrical conductivity than Mg.
- A Z atom has a half-filled subshell in its ground state.
- Z forms an acidic oxide on exposure to air.

What is Z?

- A** Na **B** Si **C** P **D** Cl

27. In hydrogen atoms, the four electron transitions below result in the emission of photons of different frequencies.

Which transition results in the emission of a photon of the highest frequency?

- A** 3s → 2p **B** 4p → 3s **C** 5p → 4d **D** 6d → 5p

28. Which element in period 3 is **not** correctly described?

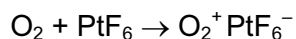
	element	bonding	structure
A	chlorine	covalent	simple
B	magnesium	metallic	giant
C	phosphorus	covalent	simple
D	silicon	covalent	simple

29. An ion of manganese has an electronic configuration of $[\text{Ar}]3d^4$.

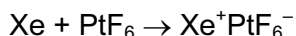
Which compound contains this ion?

- A** MnCl_2 **B** MnO **C** Mn_2O_3 **D** MnO_2

30. Oxygen reacts with platinum(VI) fluoride, PtF_6 , as shown.



When the first noble gas compound was produced in 1962, it was suggested that xenon should react similarly.



What is the most likely reason for this suggestion being made?

- A** O and Xe have similar electron affinities.
B O and Xe have similar ionic radii.
C O_2 and Xe have similar electron configurations.
D O_2 and Xe have similar first ionisation energies.
31. The table shows the successive ionisation energies for an element Q.

	1st	2nd	3rd	4th
ionisation energy/ kJ mol^{-1}	418	3070	4600	5860

What is the likely formula of the oxide of Q?

- A** QO **B** Q_3O_2 **C** Q_2O **D** Q_2O_3

32. Four elements, W, X, Y and Z, are in the potassium to krypton period with consecutive atomic numbers. The table shows the number of unpaired electrons in each atom in its ground state.

element	W	X	Y	Z
unpaired electrons	2	1	0	1

In which group of the Periodic Table is element W?

- A** 4 **B** 10 **C** 14 **D** 16

33. When the N_2^+ ion is formed from N_2 a σ bonding electron is removed. Which statement is correct?
- A** The bond order decreases so N_2^+ has a stronger, shorter bond than N_2 .
- B** The bond order decreases so N_2^+ has a weaker, longer bond than N_2 .
- C** The bond order increases so N_2^+ has a stronger, shorter bond than N_2 .
- D** The bond order increases so N_2^+ has a weaker, longer bond than N_2 .
34. Which atom has the highest ratio of unpaired electrons to paired electrons in its ground state?
- A** boron
- B** carbon
- C** nitrogen
- D** oxygen
35. The double salt $(\text{NH}_4)_2\text{SO}_4 \cdot \text{FeSO}_4 \cdot 6\text{H}_2\text{O}$ is used as a standard in volumetric analysis for titrations with oxidising agents.

What is the electronic configuration of the metal ion in this salt?

- A** $[\text{Ar}]4s^23d^6$ **B** $[\text{Ar}]4s^23d^4$ **C** $[\text{Ar}]3d^6$ **D** $[\text{Ar}]3d^5$

36. Which sequence of first ionisation energies for the elements of the third period is correct?

	energies / kJ mol^{-1}							
	Na	Mg	Al	Si	P	S	Cl	Ar
A	496	578	738	789	1000	1060	1251	1521
B	496	738	578	789	1000	1060	1251	1521
C	496	578	738	789	1012	1000	1251	1521
D	496	738	578	789	1012	1000	1251	1521

Covalent Bonding

37. Antimony can be produced in a two-stage process from its ore stibnite, Sb_2S_3 .

The ore is first roasted in oxygen, producing Sb_4O_6 and SO_2 .

The Sb_4O_6 is then reduced by carbon, producing Sb and CO_2 .

What volume of CO_2 , measured at room temperature and pressure, is produced on processing 10 moles of Sb_2S_3 ?

- A** 15 dm^3 **B** 180 dm^3 **C** 360 dm^3 **D** 720 dm^3

38. A covalent molecule contains

- 14 electrons,
- one lone pair of electrons,
- two π bonds.

What is the molecule?

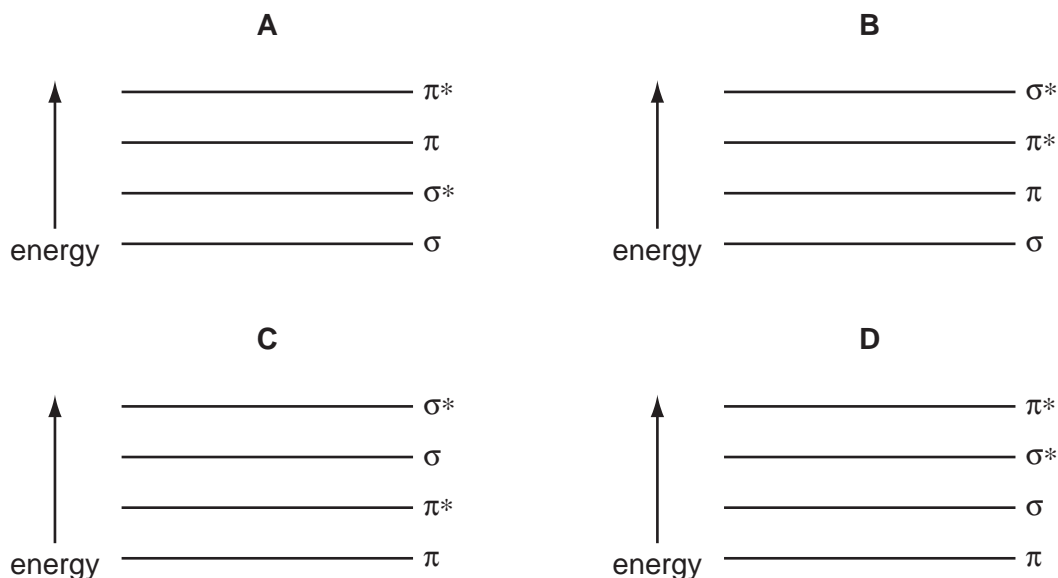
- A** C_2H_4 **B** HCN **C** H_2O_2 **D** N_2

39. Which statement about antibonding is **not** correct?

- A** Filling an antibonding orbital lowers the bond order of a molecule by 1.
- B** For a given orbital overlap, the antibonding orbital is always higher in energy than the bonding orbital.
- C** Stable molecules cannot have any electrons in antibonding orbitals.
- D** The antibonding orbitals are found outside the region of space between the two bonding nuclei.

40. The carbon atoms in ethene are bonded through σ and π bonds. When atomic orbitals overlap they form bonding (σ and π) and antibonding (σ^* and π^*) orbitals.

What is the correct order of energies of the σ and π orbitals in an ethene molecule?



41. Cyanogen, $(\text{CN})_2$, is a colourless, toxic gas with a pungent smell. Its molecule contains a single C–C bond.

Which feature of the cyanogen molecule is **not** correct?

- A** Both carbon atoms are at a carboxylic acid functional group level.
- B** The molecule contains four π bonds.
- C** The molecule contains four lone pairs of electrons.
- D** The molecule is linear.
42. In which pair of molecules are the values of the bond angles the closest?
- A** BF_3 and NH_3
- B** C_2H_4 and BF_3
- C** H_2O and C_2H_4
- D** CH_4 and H_2O

43. Which shows the chemical bonds in order of increasing bond length?

- A** Cl-Cl F-F O=O $\text{N}\equiv\text{N}$
- B** F-F Cl-Cl O=O $\text{N}\equiv\text{N}$
- C** $\text{N}\equiv\text{N}$ O=O Cl-Cl F-F
- D** $\text{N}\equiv\text{N}$ O=O F-F Cl-Cl

44. Which statement about bond formation is **not** correct?

- A** A triple bond consists of one σ bond and two π bonds.
- B** A π bond restricts rotation about the σ bond axis.
- C** Bonds formed from atomic s orbitals are always σ bonds.
- D** End-to-end orbital overlap results in a bond with electron density above and below the bond axis.

Non-Covalent Bonding

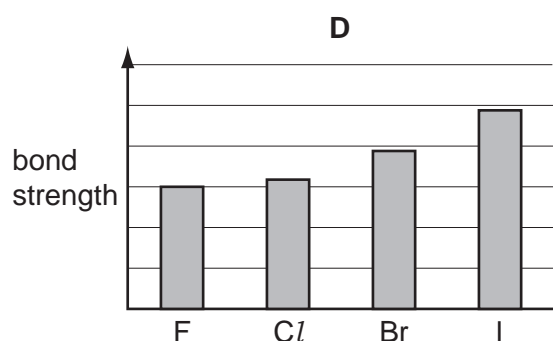
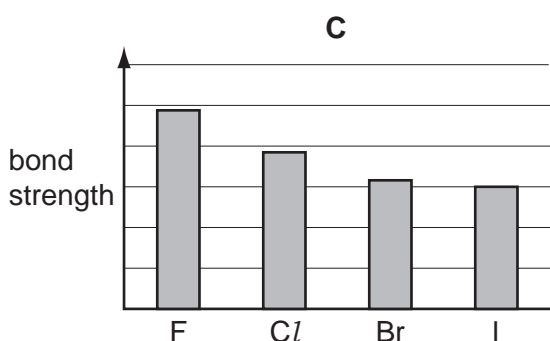
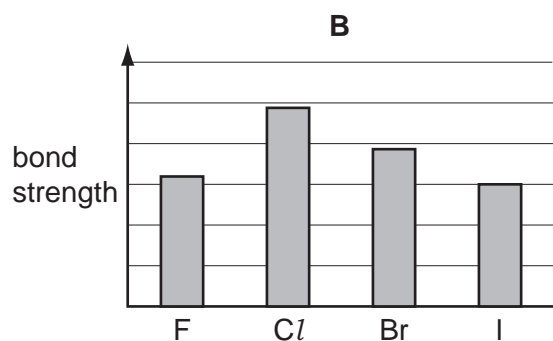
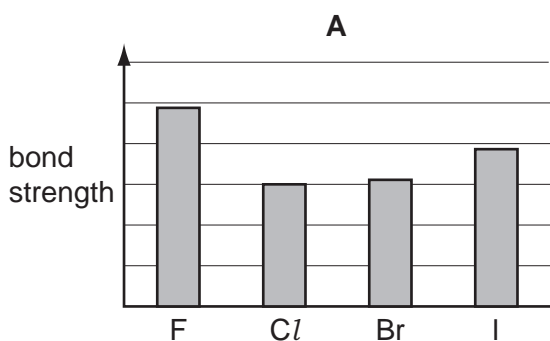
45. Group I elements form diatomic molecules in the gas phase. Which molecule has the **smallest** dipole moment?

- A Na—Li
- B Na—Na
- C Na—Rb
- D Na—Cs

46. In which process are hydrogen bonds broken?

- A $\text{H}_2(\text{l}) \rightarrow \text{H}_2(\text{g})$
- B $\text{NH}_3(\text{l}) \rightarrow \text{NH}_3(\text{g})$
- C $2\text{HI}(\text{g}) \rightarrow \text{H}_2(\text{g}) + \text{I}_2(\text{g})$
- D $\text{CH}_4(\text{g}) \rightarrow \text{C}(\text{g}) + 4\text{H}(\text{g})$

47. How does the strength of the halogen-halogen covalent bond change as Group 17 is descended?



48. The shape of the PCl_5 molecule in the gas phase is trigonal bipyramidal.

The chlorine atoms can be replaced one at a time by fluorine atoms, the axial chlorine atoms being replaced first, then the equatorial atoms.

Which molecule does **not** have a dipole moment?

- A** PClF_4 **B** PCl_2F_3 **C** PCl_3F_2 **D** PCl_4F

49. The alkanes used to be known as the paraffin hydrocarbons - paraffin meaning 'lack of affinity' (i.e. unreactive).

Which statement is the best explanation of the 'lack of affinity' in alkanes?

- A** The atoms are arranged tetrahedrally around each carbon atom.
B The intermolecular forces are van der Waals forces.
C There are no significant dipole moments in C–H and C–C bonds.
D There is free rotation about C–C single bonds.