PHYSICAL CHEMISTRY 1 PRACTISE QUESTIONS

1 The Pauling electronegativity values of elements can be used to predict the chemical properties of compounds.

Use the information in Table 1.1 to answer the following questions.

Table 1.1

element	H	Li	C	O	S
Pauling electronegativity value	2.1	1.0	2.5	3.5	2.6
first ionisation energy / kJ mol^{-1}	1310	519	1090	1310	1000
second ionisation energy / kJ mol^{-1}	—	7300	2350	3390	2260

(a) (i) Define electronegativity.

.....

..... [1]

(ii) O and S are in Group 16.

Explain the difference in the Pauling electronegativity values of O and S.

.....

.....

..... [2]

(b) (i) LiH is an ionic compound.

Draw a dot-and-cross diagram of LiH.

Include **all** electrons.

[2]

(ii) Suggest the shape of a molecule of H_2S.

..... [1]

(c) **(i)** Write an equation that represents the first ionisation energy of H.

..... [1]

(ii) Explain why there is no information given in Table 1.1 for the second ionisation energy of H.

..... [1]

(iii) Give the full electronic configuration of $S^{2+}(g)$.

..... [1]

(d) CO_2 and SO_2 are acidic gases.

(i) Write an equation for the reaction of SO_2 with H_2O.

..... [1]

(ii) Write an equation for the reaction of SO_2 with NaOH.

..... [1]

(iii) Construct an equation for the reaction of CO_2 with $Mg(OH)_2$.

..... [1]

(e) (i) Complete Table 1.2 by placing a tick (✓) to show which of the compounds have molecules with an overall dipole moment.

Table 1.2

compound	O=C=O	O=S=O	S=C=S	S=C=O
overall dipole moment				

[2]

(ii) At 150 °C and 103 kPa, all of the compounds listed in Table 1.2 are gases.

Under these conditions, 0.284 g of one of the compounds occupies a volume of 127 cm^3.

Use this information to calculate the M_r of the compound. Hence, identify the compound from those given in Table 1.2.

Show your working.

M_r = ... identity of compound = ...

[3]

[Total: 17]

The Group 2 elements Mg to Ba are all silvery-white reactive metals.

(a) **(i)** Draw a labelled diagram to show the bonding and structure of the Group 2 metals at room temperature.

[2]

(ii) Explain why Mg has a higher electrical conductivity than Na.

.....

..... [1]

(b) Write an equation for the reaction of magnesium with cold water.

..... [1]

(c) Identify a single reagent that can be used to distinguish separate samples of dilute $Mg(NO_3)_2(aq)$ and dilute $Ba(NO_3)_2(aq)$.

Explain your answer.

reagent .....

explanation .....

.....

[2]

(d) **(i)** Describe what is observed when $SrI_2(aq)$ reacts with concentrated sulfuric acid.

.....

..... [2]

(ii) Compound **X**, an anhydrous Group 2 bromide, is dissolved in water and titrated against aqueous silver nitrate.

A solution containing 0.250 g of **X** requires 33.65 cm^3 of 0.0500 mol dm^{-3} $AgNO_3(aq)$ for complete reaction.

Identify **X**.

Show your working.

X = ... [3]

[Total: 11]

Tellurium is an element in Group 16. The most common isotope of tellurium is ^{130}Te. Its electronic configuration is [Kr] $4d^{10}\ 5s^2\ 5p^4$.

(a) Complete Table 1.1.

Table 1.1

	nucleon number	number of neutrons	number of electrons
^{130}Te			

[3]

(b) Identify the sub-shell in an atom of Te that contains electrons with the lowest energy.

..... [1]

(c) Construct an equation to represent the first ionisation energy of Te.

..... [1]

(d) **(i)** The radius of Te ions decreases after each successive ionisation.

State **two** factors that are responsible for the increase in the first six ionisation energies of Te.

.....

.....

..... [2]

(ii) Sketch a graph in Fig. 1.1 to show the trend in the first **seven** ionisation energies of Te.

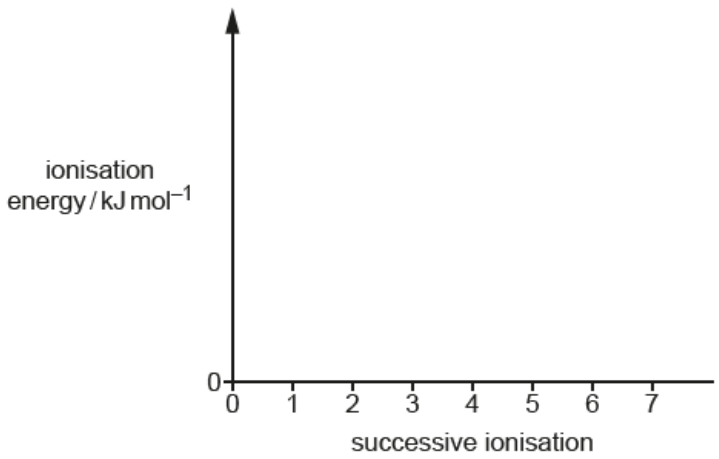

Fig. 1.1

[2]

(e) Te reacts with F_2 at 150 °C to form TeF_x. Molecules of TeF_x are octahedral with bond angles of 90°.

Explain why TeF_x is octahedral with bond angles of 90°.

.....

.....

..... [2]

(f) TeF_x reacts with water to form tellurium hydroxide and HF. The oxidation number of tellurium does **not** change during this reaction.

(i) Construct an equation for the reaction of TeF_x with water.

..... [1]

(ii) Name the type of reaction that occurs when TeF_x reacts with water.

..... [1]

[Total: 13]

A neutralisation reaction occurs when NaOH(aq) is added to $H_2SO_4(aq)$.

equation 1 $2NaOH(aq) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$

(a) Define enthalpy change of neutralisation, ΔH_{neut}.

.....

.....

..... [2]

(b) An experiment is carried out to calculate ΔH_{neut} for the reaction between NaOH(aq) and $H_2SO_4(aq)$.

$100\,cm^3$ of $1.00\,mol\,dm^{-3}$ NaOH(aq) is added to $75\,cm^3$ of $1.00\,mol\,dm^{-3}$ $H_2SO_4(aq)$ in a polystyrene cup and stirred. Results from the experiment are shown in Table 2.1.

Table 2.1

initial temperature of NaOH(aq)/°C	20.0
initial temperature of $H_2SO_4(aq)$/°C	20.0
maximum temperature of mixture/°C	27.8

(i) Use equation 1 to calculate the amount, in mol, of $H_2SO_4(aq)$ that is neutralised in the experiment.

amount of $H_2SO_4(aq)$ neutralised = ... mol [1]

(ii) Calculate ΔH_{neut} using the results in Table 2.1. Include units in your answer.

Assume that:
- the specific heat capacity of the final solution is $4.18\,J\,g^{-1}\,K^{-1}$
- $1.00\,cm^3$ of the final solution has a mass of 1.00 g
- there is no heat loss to the surroundings
- full dissociation of $H_2SO_4(aq)$ occurs
- the experiment takes place at constant pressure.

Show your working.

ΔH_{neut} = ... units .....
[3]

1 The melting points of some solids are shown in Table 1.1.

Table 1.1

solid	melting point/K
magnesium	923
phosphorus	317
sodium chloride	1074
sulfur	392

(a) (i) State the type of bonding present in magnesium and in sodium chloride.

bonding in magnesium .....

bonding in sodium chloride .....

[1]

(ii) Explain the difference in the melting points of magnesium and sodium chloride.

.....

..... [1]

(iii) Explain the difference in the melting points of phosphorus and sulfur in terms of structure and bonding.

.....

.....

..... [2]

(b) (i) Define electronegativity.

.....

..... [1]

(ii) Explain why electronegativity increases across a period.

.....

.....

..... [2]

(iii) Name the strongest intermolecular force that exists between $NH_3(l)$ molecules.

..... [1]

(iv) Draw a diagram to show the formation of the strongest intermolecular force between **two** molecules of $NH_3(l)$.

Include any relevant lone pairs of electrons and dipoles.

[2]

(v) The melting points of ice and ammonia are shown in Table 1.2.

Table 1.2

solid	melting point / K
ice	273
ammonia	195

Suggest **two** reasons for the difference in the melting points of ice and ammonia.

.....

.....

..... [2]

[Total: 12]

1 The elements phosphorus, sulfur and chlorine are in Period 3 of the Periodic Table.

Table 1.1 shows some properties of the elements P to C*l*.

The first ionisation energy of S is **not** shown.

Table 1.1

property	P	S	C*l*
number of electrons in 3p subshell			
total number of unpaired electrons			
first ionisation energy /kJ mol^{-1}	1060		1260
formula of most common anion	P^{3-}	S^{2-}	Cl^{-}

(a) (i) Complete Table 1.1 to show the number of electrons in the 3p subshell and the total number of unpaired electrons in an atom of P, S and C*l*. [2]

(ii) Construct an equation to represent the first ionisation energy of P.

..... [1]

(iii) Three possible values for the first ionisation energy of S are given.

1000 kJ mol^{-1} **1160 kJ mol^{-1}** **1320 kJ mol^{-1}**

Circle the correct value.

Explain your choice by comparing your chosen value to those of P and C*l*.

.....

.....

.....

.....

.....

..... [4]

3

(b) P^{3-}, S^{2-} and Cl^- have the same number of electrons.

(i) Give the full electronic configuration of P^{3-}.

..... [1]

(ii) State the trend in ionic radius shown by P^{3-}, S^{2-} and Cl^-.

Explain your answer.

.....

.....

.....

..... [2]

(c) A student does three tests on separate samples of NaCl(aq).

Complete Table 1.2 with the observations the student makes in each test.

Table 1.2

test	test	observations
1	addition of a few drops of $Br_2(aq)$	
2	addition of a few drops of concentrated H_2SO_4	
3	addition of a few drops of dilute $AgNO_3(aq)$	

[3]

(d) $POCl_3$ shows similar chemical properties to PCl_5.

$POCl_3$ has a melting point of 1°C and a boiling point of 106 °C.

$POCl_3$ reacts vigorously with water, forming misty fumes and an acidic solution.

(i) Explain how the information in **(d)** suggests the structure and bonding of $POCl_3$ is simple covalent.

.....

.....

..... [2]

(ii) Construct an equation for the reaction of $POCl_3$ with water.

$POCl_3$ + ... → .....

[1]

(iii) $POCl_3$ contains a double covalent bond between P and O.

Complete the dot-and-cross diagram, in Fig. 1.1, to show the bonding in $POCl_3$.

Show outer shell electrons only.

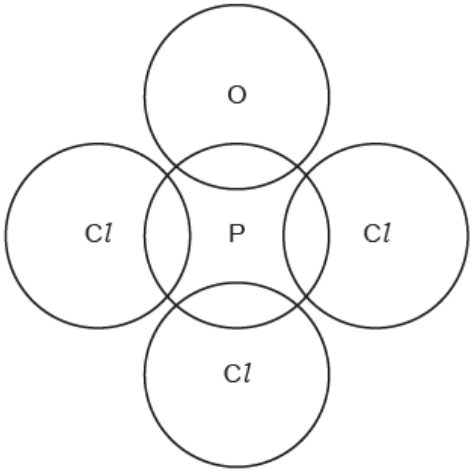

Fig. 1.1

[2]

(e) $POCl_3(g)$ forms when $PCl_3(g)$ reacts with $O_2(g)$.

$$2PCl_3(g) + O_2(g) \rightarrow 2POCl_3(g)$$

Table 1.3 gives some relevant data.

Table 1.3

process	value / kJ mol^{-1}
enthalpy change of formation of $PCl_3(g)$	–289
enthalpy change of formation of $POCl_3(g)$	–592
$O_2(g) \rightarrow 2O(g)$	+496

(i) Define enthalpy change of formation, ΔH_f.

.....

.....

..... [2]

(ii) Calculate the bond energy of P=O in $POCl_3$ using the data in Table 1.3.

Show your working.

bond energy of P=O = ... kJ mol^{-1}
[2]

The elements silicon, phosphorus and sulfur are in Period 3 of the Periodic Table.

(a) (i) Describe the variation in atomic radius from silicon to sulfur.

..... [1]

(ii) The melting point of silicon is 1410 °C. The melting point of sulfur is 113 °C.

Explain this difference.

.....

.....

.....

..... [3]

(b) Table 1.1 shows some properties of the elements Si to S.

The first ionisation energy of P is **not** shown.

Table 1.1

property	Si	P	S
total number of electrons in s subshells			
total number of electrons in p subshells			
first ionisation energy / kJ mol^{-1}	786		1000
formula of most common chloride	$SiCl_4$	PCl_5	SCl_2

(i) Complete Table 1.1 to show the total number of s and p electrons in an atom of Si, P and S.

[2]

(ii) Construct an equation to represent the first ionisation energy of Si.

..... [1]

(iii) Three possible values for the first ionisation energy of P are given.

619 kJ mol^{-1} **893 kJ mol^{-1}** **1060 kJ mol^{-1}**

Circle the correct value.

Explain your choice, including a comparison of your chosen value to those of Si and S.

.....

.....

.....

.....

.....

..... [4]

(iv) $SiCl_4$ and PCl_5 each react with water, forming misty fumes.

Identify the chemical responsible for the misty fumes.

..... [1]

(v) Predict the shape of the SCl_2 molecule.

..... [1]

[Total: 13]

1 Bismuth is an element in Group 15 of the Periodic Table.

(a) Bismuth has metallic bonding.

Draw a labelled diagram to show the metallic bonding in bismuth.

[1]

(b) Bismuth reduces water to form bismuth oxide, Bi_2O_3. A colourless gas that ignites with a squeaky pop also forms.

(i) Construct an equation for the reduction of water by bismuth.

..... [1]

(ii) Bi_2O_3 is a yellow insoluble solid that melts at 1090 K. The molten compound conducts electricity.

Deduce the structure and bonding of Bi_2O_3. Explain your answer.

.....

.....

..... [2]

(c) Bi_2O_3 can be used to form $NaBiO_3$, as shown in equation 1.

equation 1 $\quad Na_2O + Bi_2O_3 + O_2 \rightarrow 2NaBiO_3$

(i) Deduce the oxidation number of Bi in Bi_2O_3 and in $NaBiO_3$.

oxidation number of Bi:

in Bi_2O_3 ..... in $NaBiO_3$ .....
[1]

(ii) Identify the reducing agent in equation 1.

..... [1]

4

(e) $NaBiO_3$ can be used to determine the concentration of $Mn^{2+}(aq)$. The ionic equation for the reaction is shown in equation 2.

equation 2 $\quad 2Mn^{2+} + 5BiO_3^- + 14H^+ \rightarrow 2MnO_4^- + 5Bi^{3+} + 7H_2O$

A student uses the following procedure in an experiment.

- Add 100.0 cm^3 of a saturated solution of $Mn^{2+}(aq)$ to a volumetric flask.
- Add distilled water to the flask to make a 1.00 dm^3 diluted solution.
- Titrate a 25.00 cm^3 sample of the diluted solution with 0.100 mol dm^{-3} $NaBiO_3(aq)$.

The 25.00 cm^3 sample of the diluted solution of $Mn^{2+}(aq)$ reacts completely with exactly 21.50 cm^3 of 0.100 mol dm^{-3} $NaBiO_3(aq)$.

Calculate the concentration, in mol dm^{-3}, of $Mn^{2+}(aq)$ in the saturated solution.

Show your working.

concentration of $Mn^{2+}(aq)$ in the saturated solution = ... mol dm^{-3} [3]

Chlorine, Cl_2, reacts with many elements and compounds to form chlorides.

Table 2.1 shows information about some chlorides of Period 3 elements.

Table 2.1

	Na	Mg	Si
formula of chloride			
structure of chloride	giant		
bonding of chloride			covalent
pH of solution formed on addition of chloride to water		6.2	

(a) Complete Table 2.1. [3]

(b) When Cl_2 reacts with **cold** NaOH(aq), Cl_2 is both oxidised and reduced. The products are NaCl, water and **G**.

(i) State the type of redox reaction in which the same species is both oxidised and reduced.

..... [1]

(ii) Identify **G**.

..... [1]

(iii) Write an equation for the reaction between Cl_2 and **hot** NaOH(aq).

..... [1]

(iv) Describe fully what is observed when $AgNO_3$(aq) is added to the aqueous solution of the chloride of sodium, followed by dilute NH_3(aq).

.....

..... [2]

(a) Sulfur chloride, SCl_2, is a liquid at room temperature. When SCl_2 is added to water, misty fumes are seen and a solution is made that turns universal indicator red.

(i) Identify the type of reaction that occurs when SCl_2 is added to water.

..... [1]

(ii) Name a chloride of a different Period 3 element that is also a liquid at room temperature and produces misty fumes when added to water.

..... [1]

(b) A molecule of SCl_2 contains two S–Cl covalent bonds.

(i) Complete the dot-and-cross diagram in Fig. 2.1 to show the arrangement of the outer electrons in a molecule of SCl_2.

Use x to show electrons from the chlorine atoms.
Use • to show electrons from the sulfur atom.

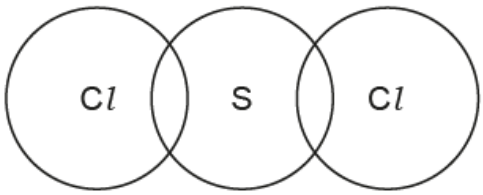

Fig. 2.1

[2]

(ii) Predict the shape of, and bond angle in, a molecule of SCl_2 by using VSEPR theory.

shape .....

bond angle .....

[2]

1 **(a)** The elements of Group 17 are called halogens.

Complete Table 1.1.

Table 1.1

halogen	colour at 293 K
chlorine	
bromine	
iodine	

[1]

(b) State the trend in volatility of the halogens chlorine, bromine and iodine. Explain your answer.

.....

.....

.....

..... [3]

(c) Iodine is made by reacting bromine with sodium iodide.

(i) Construct an ionic equation for the reaction of bromine with sodium iodide.

..... [1]

(ii) State the role of bromine in the reaction. Explain your answer.

.....

..... [1]

(a) Complete Table 1.1 using relevant information from the Periodic Table.

Table 1.1

	nucleon number	proton number	number of electrons
Mg^{2+}	24		
Al^{3+}	27		

[2]

(b) State and explain the difference in the ionic radius of Al^{3+} compared to Mg^{2+}.

.....

.....

.....

..... [3]

(c) Draw a labelled diagram to show the structure and bonding in sodium.

[1]

(d) Fig. 1.1 shows the variation in melting point of some Period 3 elements in their standard states at room temperature and pressure.

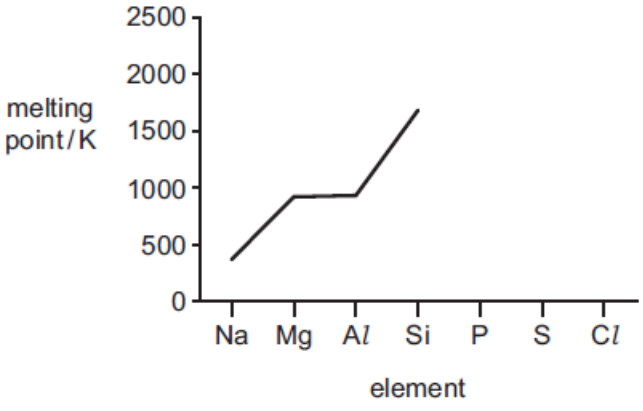

Fig. 1.1

(i) Explain why Si has a high melting point.

.....

.....

..... [1]

(ii) Complete Fig. 1.1 to show the variation in the melting points of the elements P, S and C*l*.
[2]

(a) (i) Explain the lack of reactivity of nitrogen gas, $N_2(g)$.

.....

.....

..... [2]

(ii) Covalent bonds can be σ bonds or π bonds.

Complete Table 1.1 to show the number of σ and π bonds in a molecule of N_2 and to describe how the orbitals overlap to form σ and π bonds.

Table 1.1

	σ bond	π bond
number of bonds in N_2		
how the orbitals overlap		

[4]

(b) (i) A sample of Al reacts with an excess of Cl_2.

State the oxidation number of Al in the product of the reaction.

oxidation number of Al ..... [1]

(ii) State what determines the maximum oxidation number of the Period 3 elements in their oxides.

.....

..... [1]

3 **(a)** Write an equation to show the reaction for the standard enthalpy change of formation of H_2O. Include state symbols.

..... [2]

(b) Water is one of the products in the reaction of B_2O_3 and NH_3, as shown in reaction 2.

reaction 2 $B_2O_3 + 2NH_3 \rightarrow 2BN + 3H_2O$

Table 3.1 shows information about the standard enthalpy change of formation, $\Delta H_f^{\ominus}$, of some substances.

Table 3.1

substance	$\Delta H_f^{\ominus}$ / kJ mol^{-1}
B_2O_3	–1264
NH_3	–46
BN	–134
H_2O	–286

Calculate the enthalpy change, ΔH, for reaction 2 using the data from Table 3.1.

ΔH = ... kJ mol^{-1} [2]

(c) Boron carbide is a hard crystalline solid that has a melting point greater than 2000 °C.

(i) Suggest the structure and bonding in boron carbide.

..... [1]

(ii) 100 g of pure boron carbide contains 78.26 g of boron.

Calculate the empirical formula of boron carbide.

Show your working.

empirical formula of boron carbide ..... [2]

(a) $NH_3(g)$ reacts with $HCl(g)$ to produce $NH_4Cl(s)$, as shown.

$$NH_3(g) + HCl(g) \rightarrow NH_4Cl(s)$$

Draw a diagram to show the ionic, covalent and coordinate bonding present in a formula unit of NH_4Cl.

[2]

(b) An exothermic reaction occurs when $NH_4^+(aq)$ is added to $OH^-(aq)$.

(i) Identify the type of reaction.

..... [1]

(ii) Construct an ionic equation for the reaction of NH_4^+ and OH^-.

..... [1]