CH1012 Tutorial 5 Answers

1. What is the partial pressure of methane in a gas vessel of 5 m^3 containing 16.0 g of methane (CH_4) and 32.0 g of oxygen at 297.8K.

MCH_4	= (1 x 12.0) + (4 x 1.0)	= 16.0 g mol^{-1}
MO_2	= (2 x 16.0)	= 32.0 g mol^{-1}
nCH_4	= 16.0 g/ 16.0 g mol^{-1}	= 1.00 mol
nO_2	= 32.0 g / 32.0 g mol^{-1}	= 1.00 mol
nTotal	= nCH_4 + nO_2	= 2.00 mol
XCH4	= nCH4 / nTotal	= 0.500
XO2	= nO2 / nTotal	= 0.500
pTotal	= nTotal R T / V	= 2.00 mol x 8.31 Pa m^3 $K^{-1}mol^{-1}$ x 297.8 T / 5.00 m^3 = 990 Pa
pCH4	= XCH_4 x pTotal	= 0.500 x 990 **= 495 Pa**

2. What are the **van der Waals forces** and how do they affect the normal boiling point of liquids?

The van der Waals Forces are the weak intermolecular forces between molecules (atoms). They include forces such as (i) hydrogen bonding, (ii) dipole-dipole, (iii) dispersion forces (instantaneous dipoles).
The normal boiling of a liquid occurs when the vapour pressure above the liquid is equal to 1 atmosphere pressure (the external pressure). As the van der Waals Forces hold the liquid particles together it takes more energy to eject the particles into the gas phase with these forces in operation. This means that a higher temperature is required to boil a liquid due to influence of the van der Waals Forces than would be the case if they did not exist.

3. What is an atomic orbital?

An atomic orbital is a mathematical function which is a solution to the Schrodinger equation HΨ=EΨ. It is synonymous with the term wavefunction, and is a *descriptor of the motion of the electron as a function of time and position as it orbits the nucleus,* the square of the wavefunction gives the probability of finding an electron at a particular point in the atom. An atomic orbital is defined by the quantum numbers n, l and m_l, typical orbitals are s, p, d and f, each orbital can hold a maximum of 2 electrons and has a quantised energy.

4. What are the quantum numbers that define a 5s orbital? Give their values.

Principle quantum number n = 5
angular quantum number l = 0

5. Calculate the temperature at which n-butanol will boil at a pressure of 2666.4 Pa, if the normal boiling point is 118°C. ΔH_v (n-butanol) = 44.5 kJ mol^{-1}.

$$\ell n\left(\frac{P_2}{P_1}\right) = \frac{-H_{vap}}{R}\left(\frac{1}{T_2}-\frac{1}{T_1}\right)$$

$$\left[\frac{-R}{H_{vap}}\ell n\left(\frac{P_2}{P_1}\right)\right]+\frac{1}{T_1}=\frac{1}{T_2}$$

$$\left[\frac{-8.314}{44.5 \times 10^3} \ell n\left(\frac{2666.4}{1.013 \times 10^5}\right)\right] + \frac{1}{391} = \frac{1}{T_2}$$

$6.7957 \times 10^{-4} + 0.002557 = 1/T_2$

$T_2 = 308.9$ K

= **36°C** (to 2 significant figures)

6. Describe the main features of the production of **copper metal** from the copper ore chalcopyrite.

Copper ores such chalcopyrite have a low %Cu (around 0.5%) and are typically pre-treated either by floatation and cycloning to increase the concentration to around 15%Cu.
Following on from this an ore such as $CuFS_2$ is roasted where the sulphide ion carries out the reduction of the Cu^{n+} to Cu^o. As this is a heating process it is referred to as pyrometallurgy.

$$2CuFeS_{2(s)} + 3O_{2(g)} \rightarrow 2FeO_{(s)} + 2CuS_{(s)} + 2SO_{2(g)}$$
$$CuS_{(s)} + O_{2(g)} \rightarrow Cu_{(l)} + SO_{2(g)}\uparrow$$

Electrochemical purification (electrolysis) completes the process and takes the crude copper up to 99.9% purity.

$$\text{Cu(crude)} \rightarrow Cu^{2+} + 2e \text{ (anode)} \quad (\& \; Ni^{2+} \; \& \; Fe^{2+})$$
$$Cu^{2+} + 2e \rightarrow \text{Cu(pure) (cathode)} \quad (\underline{\text{not}} \text{ Ni \& Fe})$$

The noble metals (Au, Ag, Pt) are not oxidised at the potential required to oxidise copper (more +ve E^o values) and they fall to the bottom of the cell as the anode is eroded away to form anodic mud.
The overpotential used to oxidise the copper at the anode also results in the oxidation of the impurity metals such as Ni and Fe. These other impurities such as Ni^{2+} and Fe^{2+} are not reduced at the cathode at the potential required to reduce copper +0.34V as they have more -ve E^o values (-0.25, -0.44). Copper metal plates on the pure cathode.

7. Explain the characteristics of **network covalent ceramics** using examples to illustrate your answer.

Network covalent solids contain directional covalent bonds in large networks or chains throughout the structure. Properties are atypical of covalent compounds: high mp., bp., brittle.
Ceramics are inorganic, non-metallic, solid materials. They are divided structurally into amorphous and crystalline materials. The network covalent ceramics are in the crystalline structural type.
Examples:
BN Nitrides, the cubic form Borazon is formed at 2000°C and 150 000 atm. this compound is as hard as diamond is used as an abrasive.
SiC Carbides, SiC usually called carborundum is a very hard network ceramic solid used in cutting tools and composite cutting tools, it is stable at high temperatures.