1.1 EM Radiation

1. Which of the following is **not** a form of electromagnetic radiation?

A Beta

B Gamma

C Infrared

D Ultraviolet

2. Which of the following is **not** a form of electromagnetic radiation?

A α radiation

B γ radiation

C UV radiation

D X-rays

3. Which of the following lists electromagnetic radiation bands in order of increasing wavelength?

A X-ray, infrared, ultraviolet, radio

B Infrared, ultraviolet, X-ray, gamma

C Ultraviolet, visible, infrared, radio

D Radio, infrared, visible, gamma

4. Which of the following lists electromagnetic radiation bands in order of increasing frequency?

A Ultraviolet, visible, infra-red, radio

B Radio, infra-red, visible, ultraviolet

C Radio, microwave, ultraviolet, visible

D Visible, ultraviolet, X-ray, microwave

5 . Infrared radiation can be used in the analysis and identification of organic compounds. Compared to visible radiation, infrared radiation has a

A shorter wavelength and higher frequency

B longer wavelength and lower velocity

C longer wavelength and lower frequency

D shorter wavelength and higher velocity.

1.1 Energy, Frequency & Wavelength Calculations

1 The energy associated with a photon of electromagnetic radiation is

A independent of the frequency

B proportional to the frequency

C inversely proportional to the frequency

D proportional to the square of the frequency.

2 The energy, in $kJ\,mol^{-1}$, corresponding to light of wavelength 501 nm is

A $1{\cdot}99 \times 10^{-7}$

B 60·0

C 239

D $2{\cdot}39 \times 10^{5}$.

3 Camphorquinone generates free radicals when exposed to radiation with a wavelength of 471 nm.

Calculate the energy, in $kJ\,mol^{-1}$, associated with this wavelength. **2**

4 The rate of the reaction between $H_2(g)$ and $I_2(g)$ can be increased using light of wavelength 578 nm.

Calculate the energy, in $kJ\,mol^{-1}$, of light corresponding to this wavelength. **2**

5 Calculate the energy, in $kJ\,mol^{-1}$, associated with blue light with a wavelength of 465 nm.

6 One example of a compound containing chlorine is vanadium(IV) chloride. It reacts vigorously with water forming a blue solution.

The blue solution absorbs light of wavelength 610 nm.

Calculate the energy, in $kJ\,mol^{-1}$, associated with this wavelength. **2**

7 The cadmium emission spectrum has a line at 644 nm.

Calculate the energy, in $kJ\,mol^{-1}$, associated with this wavelength. **2**

1.1 Energy, Frequency & Wavelength Calculations

8 The spectral line used to detect strontium in a bone sample has an energy value of 251 kJ mol^{-1}.

Calculate the wavelength, in nm, of this spectral line. **2**

9 A firework produced coloured light with energy of 193 kJ mol^{-1}.

Calculate the wavelength, in nm, of this coloured light. **2**

10 A detector in a Geiger counter contains argon which ionises when nuclear radiation passes through it.

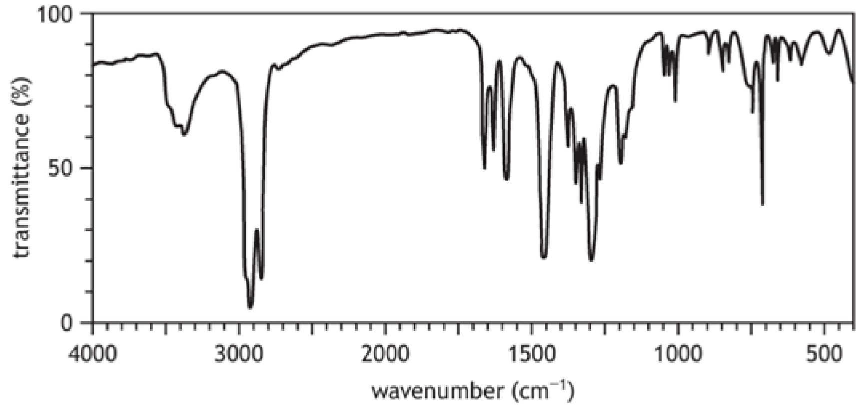
The first ionisation energy of argon is 1530 kJ mol^{-1}.

Calculate the wavelength of the radiation, in nm, corresponding to this energy.

11 A sample of strontium was exposed to electromagnetic radiation with a frequency of $3{\cdot}08 \times 10^{17}\ s^{-1}$.

Calculate the energy, in J, of this electromagnetic radiation.

12 The infrared spectrum of alizarin is shown below.



For the peak at 3395 cm^{-1} calculate

(I) the wavelength, in metres

(II) the energy, in kJ mol^{-1}, associated with this wavelength. **2**

13 The emission spectrum of an element is seen as a series of bright coloured lines against a dark background. The brightest line in the emission spectrum of sodium is seen at 589 nm.

Calculate the frequency, in Hertz, of the emission line at 589 nm

1.1 Energy, Frequency & Wavelength Calculations

14 Colorimetry is not used to determine potassium content because potassium ions are not coloured. The concentration of potassium ions in a compound can be determined using atomic absorption spectroscopy at a wavelength 405 nm.

Calculate the energy, in kJ mol^{-1}, of this radiation. **2**

15 Atomic spectroscopy is a useful analytical tool for identifying and quantifying the elements present in a sample. It also provides information about atomic structure.

When a high voltage is applied to a lamp filled with helium gas, a line of red light, wavelength 706 nm, is observed through a spectroscope.

Calculate the energy, in kJ mol^{-1}, associated with this wavelength. **2**

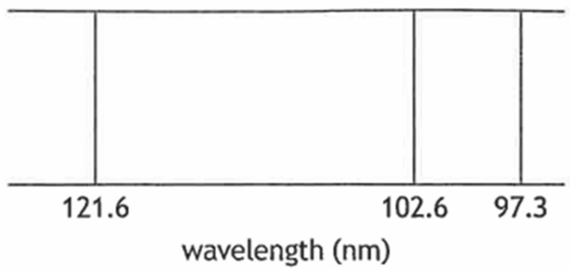
16 The first ionisation energy of sodium is 502 kJ mol^{-1}.

(i) Calculate the wavelength of light corresponding to this ionisation energy. **3**

(ii) Explain whether visible light would provide sufficient energy to ionise gaseous sodium atoms. **1**

1.1 Colour Chemistry & Atomic Spectroscopy

1 The diagram shows some lines in the hydrogen emission spectrum.



Each line in the emission spectrum

A results from an excited electron dropping to a lower energy level

B lies within the visible part of the electromagnetic spectrum

C results from an electron moving to a higher energy level

D represents an energy level within a hydrogen atom.

2 Which of the following statements about atomic emission spectroscopy is **not** correct?

A Each element has a characteristic spectrum.

B Visible light is used to promote electrons to higher energy levels.

C The lines arise from electron transitions between one energy level and another.

D The quantity of the element can be determined from the intensity of the radiation emitted.

3 In an emission spectrum of mercury, the line at 310 nm is due to

A energy from the ultraviolet region of the electromagnetic spectrum being absorbed

B energy from the ultraviolet region of the electromagnetic spectrum being released

C energy from the visible region of the electromagnetic spectrum being absorbed

D energy from the visible region of the electromagnetic spectrum being released.

4 Which of the following analytical techniques would be most suitable to determine quantitatively the concentration of sodium ions in a urine sample?

A Mass spectrometry

B Infra-red spectroscopy

C Atomic emission spectroscopy

D Proton nuclear magnetic resonance spectroscopy

5 In absorption spectroscopy, as the concentration of an ion in solution increases, there is an increase in the

A wavelength of radiation absorbed

B frequency of radiation absorbed

C intensity of radiation absorbed

D intensity of radiation transmitted.

6 In absorption spectroscopy, as the concentration of an ionic solution decreases, the radiation transmitted

A increases in intensity

B decreases in intensity

C increases in wavelength

D decreases in wavelength.

1.1 Colour Chemistry & Atomic Spectroscopy

7 Neon gas discharge lamps produce a red glow because electrons in neon atoms are

A absorbing radiation from the blue end of the visible spectrum

B emitting radiation from the red end of the visible spectrum

C emitting radiation from the blue end of the visible spectrum

D absorbing radiation from the red end of the visible spectrum.

8 Sodium vapour street lamps emit yellow light because

A sodium vapour is burning and giving out a yellow glow

B sodium vapour filters out all the light from the filament except yellow

C energy corresponding to yellow light is given out as electrons in sodium move to higher energies

D energy corresponding to yellow light is given out as electrons in sodium move to lower energies.

9 Using information from the Data Booklet which one of the following metal salts will emit radiation of the highest frequency when placed in a Bunsen flame?

A Copper(II) sulfate

B Potassium chloride

C Barium chloride

D Lithium sulfate

10 Which of the following indicators transmits only the lower frequencies of the visible spectrum at low pH?

Indicator	*Colour in acid*	*Colour in alkali*
A	Violet	Red
B	Green	Blue
C	Yellow	Violet
D	Red	Yellow

11 An aqueous solution of potassium permanganate is coloured purple. In which region of the visible spectrum is it absorbing?

A Red

B Orange

C Green

D Violet

12 Which of the following ions is **least** likely to be coloured?

A $Ti(H_2O)_6{}^{3+}$

B $Cr(NH_3)_6{}^{3+}$

C $Ni(H_2O)_6{}^{2+}$

D $Zn(NH_3)_4{}^{2+}$

13 On the basis of d $\longrightarrow$ d transitions, which of the following hydrated transition metal ions is most likely to be colourless?

A Ti^{4+}

B V^{4+}

C Co^{3+}

D Cr^{2+}

14 The colour of a highly concentrated ionic solution which absorbs light only in the ultra-violet region of the electromagnetic spectrum is

A red

B black

C violet

D colourless.

1.1 Colour Chemistry & atomic Spectroscopy

1 Some distress flares contain lithium ions and burn with an intense red light.

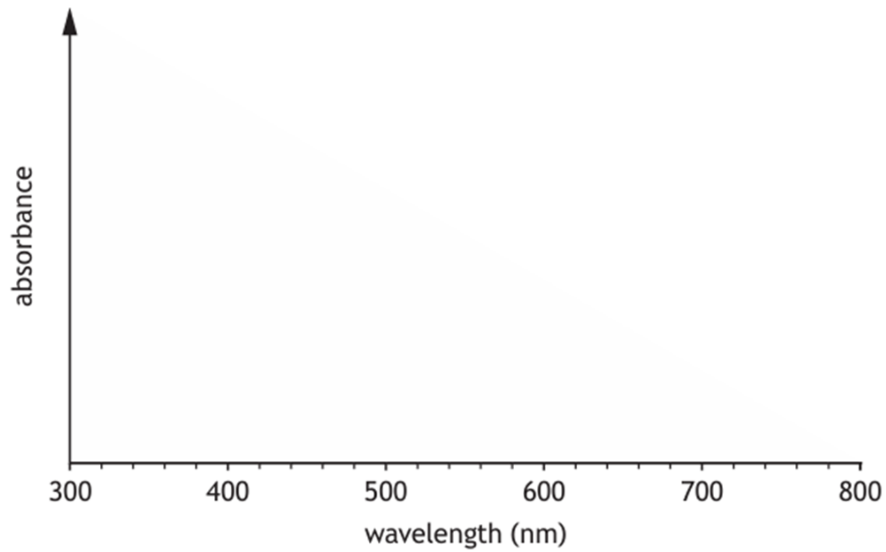
Explain, in terms of energy levels, why red light is emitted by lithium ions when distress flares are burned. **2**

2 Electron transitions involving the d subshell can give rise to colour in transition metal complexes.

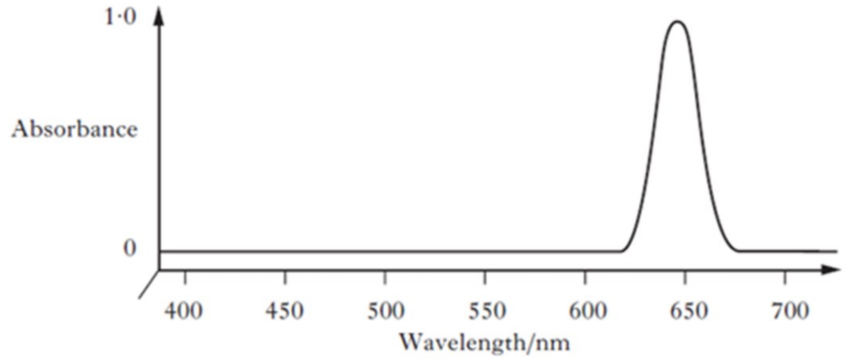
(i) Explain fully why a solution of the complex ion $[Ni(OH_2)_6]^{2+}$ is green. **2**

3 Complete the diagram below to show an absorption spectrum for a purple delphinidin.

(An additional diagram, if required, can be found on *page 35*.)



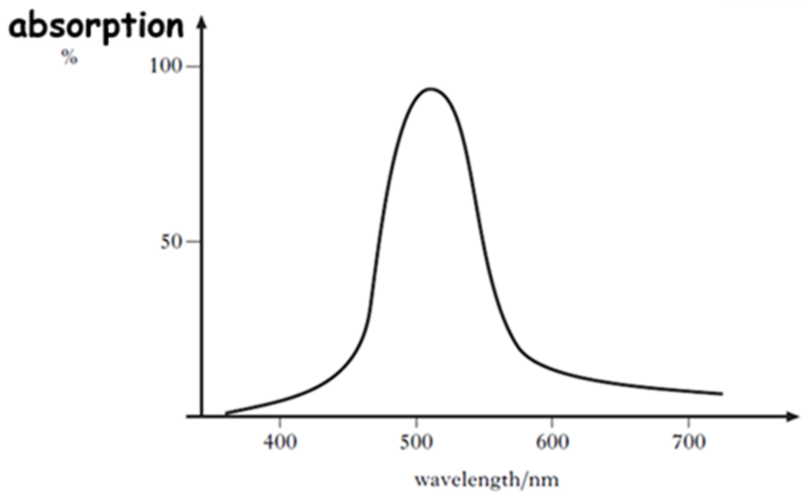
4



The absorption spectrum of a solution of sodium tetrachlorocobaltate(II) is shown above.

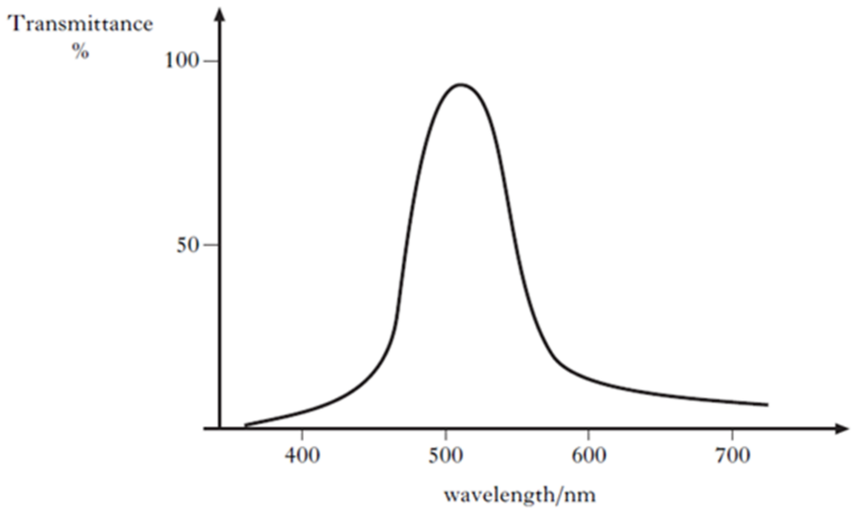
Predict the most likely colour of the solution.

5 An aqueous solution of the compound $[CoCl_2(NH_3)_4]Cl$ gave the following spectrum.



From the above spectrum, deduce the colour of the solution.

6 An aqueous solution of the compound $[CoCl_2(NH_3)_4]Cl$ gave the following **transmittance** spectrum.

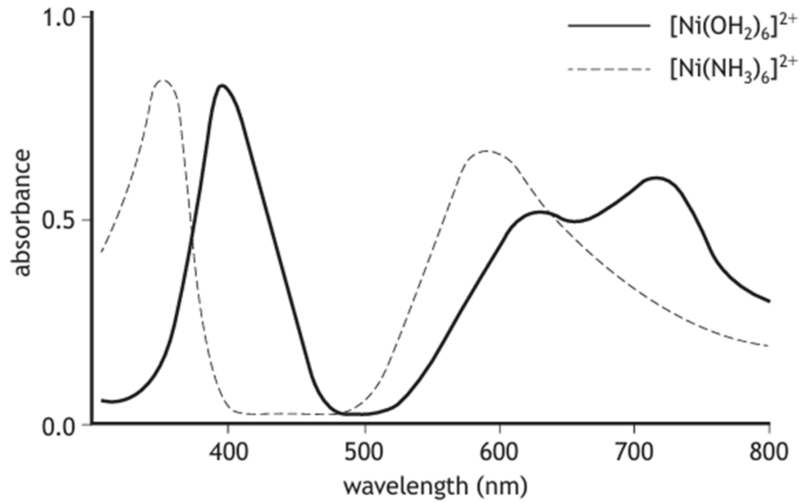


From the above spectrum, deduce the colour of the solution.

7 Mercury atoms are much larger than those of helium or phosphorus. A small section of the atomic emission spectrum for mercury is shown below.

Why does this spectrum have multiple lines? 1

8 The graph shows the absorption spectra for solutions of the complex ions $[Ni(OH_2)_6]^{2+}$ and $[Ni(NH_3)_6]^{2+}$.



Using information from the graph, explain which ligand has the greater ability to split d orbitals. 1

9 One treatment for jaundice in new-born babies is to expose them to blue light. This causes the yellow bilirubin to change into compounds that can be excreted by the body.

Suggest why blue light is used in this treatment. 1

1.1.1 Colour Chemistry & Atomic Spectroscopy

10 The manganese content of a steel paperclip can be determined by oxidising the manganese firstly into manganese(II) ions and then to the purple permanganate ion. Colorimetry is then used to find the concentration of the permanganate ion, from which the percentage manganese in the steel paperclip can be determined.

Which colour of filter or wavelength of light should be used in this procedure? **1**

11 Atomic spectroscopy is a useful analytical tool for identifying and quantifying the elements present in a sample. It also provides information about atomic structure.

When a high voltage is applied to a lamp filled with helium gas, a line of red light, wavelength 706 nm, is observed through a spectroscope.

Explain how the line of red light is produced. **2**

12 Explain why there is a series of lines at discrete wavelengths in the emission spectrum of cadmium. **1**

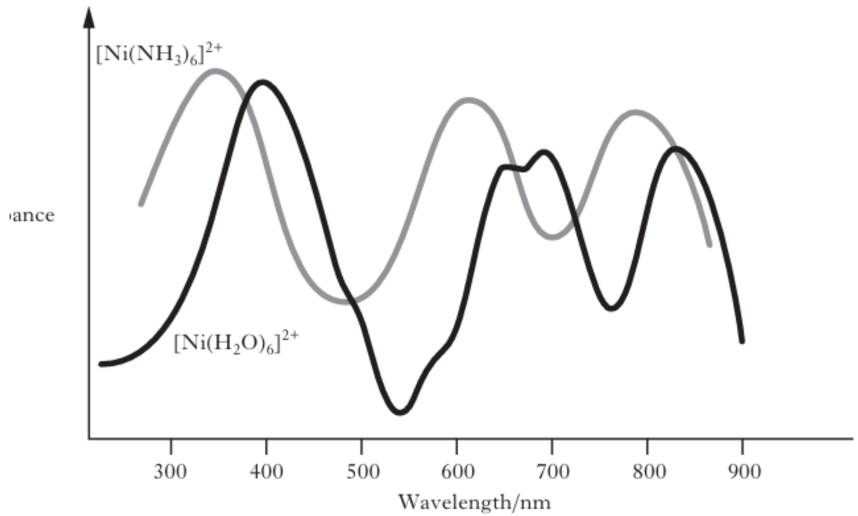
13 Strontium in bone samples can be detected by atomic emission spectroscopy.

(i) Explain how a line is produced in an emission spectrum. **1**

14 The relative ability of a ligand to split the d-orbitals when forming a complex ion is given in the spectrochemical series. Three ligands from this series and their relative ability to split the d-orbitals are shown below.

$NH_3 > H_2O > Cl^-$

The absorption spectra for $[Ni(H_2O)_6]^{2+}$ and $[Ni(NH_3)_6]^{2+}$ are shown on the following page.



(i) Why is $[Ni(H_2O)_6]^{2+}(Cl^-)_2(aq)$ likely to be green? **1**

(ii) Explain why the peaks in the absorption spectrum of $[Ni(NH_3)_6]^{2+}$ are at shorter wavelengths. **2**

(iii) Predict the colour of $[Ni(NH_3)_6]^{2+}(Cl^-)_2(aq)$. **1**

1.1.1 Colour Chemistry & Atomic Spectroscopy

15 Atomic spectroscopy is a useful analytical tool for identifying and quantifying the ele 14 present in a sample. It also provides information about atomic structure.

(*a*) When a high voltage is applied to a lamp filled with helium gas, a line of red light, wavelength 706 nm, is observed through a spectroscope.

Explain how the line of red light is produced. **2**

1.1 Energy, Frequency & Wavelength Calculations

EM Radiation

1. B
2. A
3. C
4. B
5. C

Energy, Frequency & Wavelength Calculations

1. B

2. C $E = \frac{6.02 \times 10^{23} \times 6.63 \times 10^{-34} \times 3 \times 10^{8}}{501 \times 10^{-9}}$

$2.39 \times 10^{5}\ \text{J mol}^{-1} = 239\ \text{kJ mol}^{-1}$

3. $E = \frac{6.02 \times 10^{23} \times 6.63 \times 10^{-34} \times 3 \times 10^{8}}{471 \times 10^{-9}}$

$\lambda = \frac{0.1197}{471 \times 10^{-9}} = 2.54 \times 10^{5}\ \text{J mol}^{-1} = 254\ \text{kJ mol}^{-1}$

4. $E = \frac{6.02 \times 10^{23} \times 6.63 \times 10^{-34} \times 3 \times 10^{8}}{578 \times 10^{-9}}$

$\lambda = \frac{0.1197}{578 \times 10^{-9}} = 2.07 \times 10^{5}\ \text{J mol}^{-1} = 207\ \text{kJ mol}^{-1}$

5. $E = \frac{6.02 \times 10^{23} \times 6.63 \times 10^{-34} \times 3 \times 10^{8}}{465 \times 10^{-9}}$

$\lambda = \frac{0.1197}{465 \times 10^{-9}} = 2.58 \times 10^{5}\ \text{J mol}^{-1} = 258\ \text{kJ mol}^{-1}$

6. $E = \frac{6.02 \times 10^{23} \times 6.63 \times 10^{-34} \times 3 \times 10^{8}}{610 \times 10^{-9}}$

$\lambda = \frac{0.1197}{610 \times 10^{-9}} = 1.96 \times 10^{5}\ \text{J mol}^{-1} = 196\ \text{kJ mol}^{-1}$

7. $E = \frac{6.02 \times 10^{23} \times 6.63 \times 10^{-34} \times 3 \times 10^{8}}{644 \times 10^{-9}}$

$\lambda = \frac{0.1197}{644 \times 10^{-9}} = 1.86 \times 10^{5}\ \text{J mol}^{-1} = 186\ \text{kJ mol}^{-1}$

8. $251000 = \frac{6.02 \times 10^{23} \times 6.63 \times 10^{-34} \times 3 \times 10^{8}}{\lambda}$

$\lambda = \frac{0.1197}{251\ 000} = 4.77 \times 10^{-7}\ \text{m} = 477\ \text{nm}$

9 $193000 = \frac{6.02 \times 10^{23} \times 6.63 \times 10^{-34} \times 3 \times 10^{8}}{\lambda}$

$\lambda = \frac{0.1197}{193000} = 6.22 \times 10^{-7}\ \text{m} = 622\ \text{nm}$

1.1 Energy, Frequency & Wavelength Calculations

10. $1530000 = \frac{6.02 \times 10^{23} \times 6.63 \times 10^{-34} \times 3 \times 10^{8}}{\lambda}$

$\lambda = \frac{0.1197}{1530000} = 7.83 \times 10^{-8}\ \text{m} = 78.3\ \text{nm}$

11. $E = h \times f$

$E = 6.63\times10^{-34}\ \text{J s} \times 3.08\times10^{17}\ \text{s}^{-1}$

$E = 2.04\times10^{-16}\ \text{J}$

12 (i). $\text{Wavelength} = \frac{1}{\text{Wavenumber}} = \frac{1}{3395\ \text{cm}^{-1}} = 2.96\times10^{-4}\ \text{cm} = 2.96\times10^{-6}\ \text{m}$

(ii) $E = \frac{L \times h \times c}{\lambda} = \frac{6.02\times10^{23}\ \text{mol}^{-1} \times 6.63\times10^{-34}\ \text{J s} \times 3\times10^{8}\ \text{m s}^{-1}}{2.96\times10^{-6}\ \text{m}}$

$= 40651\ \text{J mol}^{-1}$

$= 40.65\ \text{kJ mol}^{-1}$

13. $f = \frac{3.00 \times 10^{8}}{589 \times 10^{-9}}$

$f = 5.09 \times 10^{14}\ \text{Hz}$

14. $E = \frac{L \times h \times c}{\lambda} = \frac{6.02\times10^{23}\ \text{mol}^{-1} \times 6.63\times10^{-34}\ \text{J s} \times 3\times10^{8}\ \text{m s}^{-1}}{405 \times 10^{-9}\ \text{m}}$

$= 295848.9\ \text{J mol}^{-1}$

$= 296\ \text{kJ mol}^{-1}$

1.1 Energy, Frequency & Wavelength Calculations

Atomic/Emission Spectrum

1. A
2. B
3. B
4. C
5. C
6. A
7. B
8 D
9. B
10. D
11. C
12. D
13. A
14. D

1. Electrons fall to lower energy levels. (1)

   Difference in higher/lower energy levels corresponds to red light emitted. (1)

2. Purple (red & blue) light absorbed.

   This promotes electrons to higher energy d orbitals

3. Red and blue are absorbed/green light transmitted or not absorbed Light of approx.

   500 – 600 nm transmitted.

4. NH_3 results in greater ligand field splitting which means that more energy is needed to

   promote electron.

   Correct tie in with energy and wavelength for 2nd mark

5. Purple/blue-green/blue/blue-violet