Question 2

Answer the following problems about gases.

(a) The average atomic mass of naturally occurring neon is 20.18 amu. There are two common isotopes of naturally occurring neon as indicated in the table below.

Isotope	Mass (amu)
Ne-20	19.99
Ne-22	21.99

(i) Using the information above, calculate the percent abundance of each isotope.

Let x represent the natural abundance of Ne-20. $19.99x + 21.99(1-x) = 20.18$ $19.99x + 21.99 - 21.99x = 20.18$ $19.99x - 21.99x = 20.18 - 21.99$ $-2x = -1.81$ $x = 0.905$ $\Rightarrow$ percent abundances are: Ne-20 = 90.5% Ne-22 = 9.5%	One point is earned for the correct answer.

(ii) Calculate the number of Ne-22 atoms in a 12.55 g sample of naturally occurring neon.

$12.55 \text{ g Ne} \times \frac{1 \text{ mol Ne}}{20.18 \text{ g Ne}} \times \frac{0.095 \text{ mol Ne-22}}{1 \text{ mol Ne}} \times \frac{6.022 \times 10^{23} \text{ Ne-22 atoms}}{1 \text{ mol Ne-22}}$ $= 3.6 \times 10^{22}$ Ne-22 atoms	One point is earned for the correct molar mass. One point is earned for the correct fraction of Ne-22 in Ne. One point is earned for the number of atoms.

Question 2 (continued)

(b) A major line in the emission spectrum of neon corresponds to a frequency of 4.34×10^{-14} s^{-1}. Calculate the wavelength, in nanometers, of light that corresponds to this line.

$c = \lambda\nu \quad \Rightarrow \quad \lambda = \frac{c}{\nu}$ $\lambda = \frac{3.0\times10^{8}\ \text{m s}^{-1}}{4.34\times10^{14}\ \text{s}^{-1}} \times \frac{1\ \text{nm}}{10^{-9}\ \text{m}} = 690\ \text{nm}$	One point is earned for the correct setup. One point is earned for the answer.

(c) In the upper atmosphere, ozone molecules decompose as they absorb ultraviolet (UV) radiation, as shown by the equation below. Ozone serves to block harmful ultraviolet radiation that comes from the Sun.

$$O_3(g) \xrightarrow{\text{UV}} O_2(g) + O(g)$$

A molecule of $O_3(g)$ absorbs a photon with a frequency of 1.00×10^{15} s^{-1}.

(i) How much energy, in joules, does the $O_3(g)$ molecule absorb per photon?

$E = h\nu$ $= 6.63 \times 10^{-34}\ \text{J s} \times 1.00 \times 10^{15}\ \text{s}^{-1}$ $= 6.63\times10^{-19}\ \text{J}$ per photon	One point is earned for the correct answer.

(ii) The minimum energy needed to break an oxygen-oxygen bond in ozone is 387 kJ mol^{-1}. Does a photon with a frequency of 1.00×10^{15} s^{-1} have enough energy to break this bond? Support your answer with a calculation.

$\frac{6.63\times10^{-19}\ \text{J}}{1\ \text{photon}} \times \frac{6.022\times10^{23}\ \text{photons}}{1\ \text{mol}} \times \frac{1\ \text{kJ}}{10^{3}\ \text{J}} = 399\ \text{kJ mol}^{-1}$ 399 kJ mol^{-1} > 387 kJ mol^{-1}, therefore the bond can be broken.	One point is earned for calculating the energy. One point is earned for the comparison of bond energies.

2A,

2. Answer the following problems about gases.

(a) The average atomic mass of naturally occurring neon is 20.18 amu. There are two common isotopes of naturally occurring neon as indicated in the table below.

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(b) A major line in the emission spectrum of neon corresponds to a frequency of $4.34 \times 10^{14}\ s^{-1}$. Calculate the wavelength, in nanometers, of light that corresponds to this line.

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$$O_3(g) \xrightarrow{UV} O_2(g) + O(g)$$

A molecule of $O_3(g)$ absorbs a photon with a frequency of $1.00 \times 10^{15}\ s^{-1}$.

(i) How much energy, in joules, does the $O_3(g)$ molecule absorb per photon?

(ii) The minimum energy needed to break an oxygen-oxygen bond in ozone is 387 kJ mol^{-1}. Does a photon with a frequency of $1.00 \times 10^{15}\ s^{-1}$ have enough energy to break this bond? Support your answer with a calculation.

(a) (i) Suppose the abundance of Ne-20 is X

$19.99x + (1-x) \times 21.99 = 20.18$

$x = 90.5\%$

$(1-x) = 100\% - 90.5\% = 9.5\%$

The abundance of Ne-20 is 90.5%

The abundance of Ne-22 is 9.5%

(ii) $? \text{ atom Ne-22} = 12.55g \times \left(\frac{9.5\%}{100\%}\right) \times \left(\frac{1 mol}{21.99g}\right) \times \left(\frac{6.02 \times 10^{23} atoms}{1 mol}\right)$

$= 3.26 \times 10^{22}$ atoms

There are 3.26×10^{22} atoms of Ne-22

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(b) $\lambda f = c$

$\lambda = \frac{c}{f} = \frac{3\times10^8 m/s}{4.34\times10^{14}/s} = 0.691\times10^{-6} m = 691 nm$

The wavelengh is 691 nm

(c)(i) $E = h\nu$

$= 6.63\times10^{-34} J\cdot s \times 1\times10^{15} \cdot s^{-1}$

$= 6.63\times10^{-19} J$

the O_3 molecule absorbs 6.63×10^{-19} J energy per photon

(ii) Energy per mole photon $= E \times N_A$

$= 6.63\times10^{-19} J \times 6.02\times10^{23}/mol$

$= 3.99\times10^5 J/mol$

$= 399 KJ/mol$

Since Energy per mole photons exceeds 387 KJ/mole A photon with a frequency of $1\times10^{15} s^{-1}$ can break the bond.

2B,

2. Answer the following problems about gases.

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A molecule of $O_3(g)$ absorbs a photon with a frequency of $1.00 \times 10^{15}\ s^{-1}$.

(i) How much energy, in joules, does the $O_3(g)$ molecule absorb per photon?

(ii) The minimum energy needed to break an oxygen-oxygen bond in ozone is 387 kJ mol^{-1}. Does a photon with a frequency of $1.00 \times 10^{15}\ s^{-1}$ have enough energy to break this bond? Support your answer with a calculation.

a) i) $\left(\frac{x}{100} \times 19.99\text{amu}\right) + \left(\frac{100-x}{100} \times 21.99\text{amu}\right) = 20.18\text{ amu}$

$\frac{19.99x}{100}\text{amu} + \frac{2199 - 21.99x}{100}\text{amu} = 20.18\text{amu}$

$\frac{19.99x - 21.99x + 2199}{100} = 20.18\text{amu}$

$-2x + 2199 = 2018$

$-2x = -181$

$x = 90.5$

∴ For Ne-20, the % abundance is **90.5%** and for Ne-22, the % abundance is **9.5%**

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2B2

ii) Based on % abundance,
Mass of Ne-22 is $\frac{9.5}{100} \times 12.55g = 1.192\,g$ Ne-22

Based on Mass, amu,

$1.192g\ Ne\text{-}22 \times \frac{1\ mol\ Ne\text{-}22}{21.99g\ Ne\text{-}22} \times \frac{6.02 \times 10^{23}\ atoms}{1\ mol\ Ne\text{-}22}$

$= \boxed{3.264 \times 10^{22}\ Ne\text{-}22\ atoms}$

b) c = wavelength × frequency

$\frac{c}{frequency}$ = wavelength

$\frac{3.0 \times 10^{8}\ m\,s^{-1}}{4.34 \times 10^{14}\ s^{-1}}$ = wavelength

$= 6.912 \times 10^{-7}\ m$

$6.912 \times 10^{-7} m \times \frac{1 \times 10^{+9}\ nm}{1 m} = \boxed{691\ nm}$

c) i) E = hv

$E = 6.63 \times 10^{-34}\ J\,s \times 1.00 \times 10^{15}\ s^{-1}$

$= \boxed{6.63 \times 10^{-19}\ J}$ of energy per photon

ii) • From part c(i), it is identified that $1.00 \times 10^{15}\ s^{-1}$ only yields 6.63×10^{-19} J of energy.

• To break an O-O bond, $387000\ \frac{J}{mol}$ is needed.

• Therefore there is not sufficient energy to break the bonds of O-O

• Therefore it is not possible to break an O-O bond with a frequency of $1.00 \times 10^{15}\ s^{-1}$.

2C1

2. Answer the following problems about gases.

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(ii) Calculate the number of Ne-22 atoms in a 12.55 g sample of naturally occurring neon.

(b) A major line in the emission spectrum of neon corresponds to a frequency of 4.34×10^{14} s^{-1}. Calculate the wavelength, in nanometers, of light that corresponds to this line.

(c) In the upper atmosphere, ozone molecules decompose as they absorb ultraviolet (UV) radiation, as shown by the equation below. Ozone serves to block harmful ultraviolet radiation that comes from the Sun.

$$O_3(g) \xrightarrow{UV} O_2(g) + O(g)$$

A molecule of $O_3(g)$ absorbs a photon with a frequency of 1.00×10^{15} s^{-1}.

(i) How much energy, in joules, does the $O_3(g)$ molecule absorb per photon?

(ii) The minimum energy needed to break an oxygen-oxygen bond in ozone is 387 kJ mol^{-1}. Does a photon with a frequency of 1.00×10^{15} s^{-1} have enough energy to break this bond? Support your answer with a calculation.

a i) $19.99 \times \frac{x}{100} + 21.99 \times \frac{100-x}{100} = 20.18$

$19.99x + 2199 - 21.99x = 2018$

$2x = 181 \Rightarrow x = 90.5$

$\Rightarrow$ Ne-20 = 90.5%

Ne-22 = 9.5 %

ii) $\frac{m}{M} = \text{mole}$

$\frac{12.55}{21.99}$ ~~= 0.5707 mole~~

atoms $= 6.02 \times 10^{23} \times 0.5707 = 3.436 \times 10^{23}$ atoms

2C2

b) $c = \lambda\nu$

$3\times10^8 = \lambda \times 4.34\times10^{14}$

$\lambda = 6.91 \times10^{-7}$ m

c i) $E = h\nu$

$= 6.63\times10^{-34} \times 1\times10^{15}$

$= 6.63\times10^{-19}$ J

ii) Not enough!

Because 6.63×10^{-19} J << 387 kJ

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AP® CHEMISTRY
2007 SCORING COMMENTARY (Form B)

Question 2

Sample: 2A
Score: 8

This response earned 8 out of 9 points: 1 for part (a)(i), 2 for part (a)(ii), 2 for part (b), 1 for part (c)(i), and 2 for part (c)(ii). The third point was not earned in part (a)(ii) because the molar mass used for neon is 21.99 g instead of 20.18 g.

Sample: 2B
Score: 5

The point was earned in part (a)(i). Only 1 point was earned in part (a)(ii) because the molar mass used for neon is 21.99 g instead of 20.18 g, and there is also an error in significant figures. Both points were earned for part (b). The point was earned in part (c)(i). No points were earned in part (c)(ii) because the student does not calculate the energy required to break the O – O bond but rather compares energy values with different units.

Sample: 2C
Score: 4

The point was earned in part (a)(i). Only 1 point was earned in part (a)(ii) because the molar mass used for neon is 21.99 g instead of 20.18 g, and the percentage abundance is not used in the calculation. However, a point was earned for correctly calculating the number of atoms from the incorrect number of moles. Only 1 point was earned for part (b) because the answer is not given in nanometers. The point was earned in part (c)(i). No points were earned in part (c)(ii) because the student does not calculate the required energy value and compares values with different units.